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Report 0162-06-SAAS-36

AGING AND SURVEILLANCE PROGRAM MINUTEMAN II/III STAGE II PROGRAM PROGRESS

Report Period: 1 September 1985 to 15 March 1986

May 1986

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Aerojet Strategic Propulsion Company

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I. SUMMARY/RECOMMENDATION

A. PROPELLANT-LINER-INSULATION

Results of the surface hardening investigation conducted in 1984 on weathersealed motors indicate that propellant surface hardening should be considered the primary age-limiting factor for weathersealed Stage II motors. The presence of the weatherseal does not increase the rate of bore surface hardening in the humidity range from 10 to 50% RH but does decrease the rate of hydrolytic degradation of the liner.

Significant differences between Phillips and GTR CTPB propellants continue to be evident in aging trends for propellant within 1 in. of the bore surface and bondline interface of the motor. Propellant formulated with Phillips CTPB exhibits higher strength and modulus and lower strain capability and indicates a trend toward continued hardening with age. Strength and strain capability of GTR CTPB propellants both tend to decrease with age while modulus shows little change with storage time. Hardening in Phillips CTPB is due to iron contamination during manufacture: iron catalyzes oxidative cross-linking where oxygen is available (near bore and booted bond interface). All motors now being remanufactured are cast with propellant formulated with Phillips CTPB.

Data for excised samples removed from the aft end of three field-returned motors and two plug motors tested during the current report period generally support previously established trend lines in indicating (1) a difference in propellant aging trends for Phillips CTPB and GRT CTPB propellants (Page 14); (2) wide variability in properties of insulation with a trend toward hardening with age (Page 18); and (3) reduced bond strength resulting from degraded liner (Page 15).

Testing of samples excised from two early age-out motors, AA21051 and AA21434, indicates extreme liner degradation in the aft end for both motors. (Propellant properties are within the range of values experienced in

I.A. Propellant-Liner-Insulation (Cont)

comparably aged motors, Page 14.) Motor AA21051 is the second motor tested at ASPC from liner Lot L_f. This liner lot has an abnormally pink color, attributed to change in antioxidant color which occurs during aging in the mix drum. The material met acceptance specifications. Seven of 8 motors from Lot L_f were recently rejected following inspection at OO-ALC.

Analog samples have been tested for unaged propellant from 16 lot combinations. Lot Combinations 86A, 87B, and 88D are initially harder than the population average. With aging, Lot Combination 87B continues to be one of the hardest lots tested. Lot Combination 86A approaches average values with accelerated aging (Page 28).

Examination under ultraviolet light of aged propellant near the simulated bore and bondline in analog cartons confirms oxygen migration in those areas. For an analog aged 12 mo at 80°F, oxygen was present to ~3/4 in. from the bondline interface and ~1 in. from the bore. Oxygen is not present at the bondline in case-bonded samples (motor plugs, remnants). Hardening due to oxidative crosslinking should, therefore, be greatest in the booted areas of the motor. Aging trends from the bondline surfaces of analog cartons and booted regions of the motor are similar (Page 32).

Plugs have been removed from the forward and mid-barrel regions of Motor 1984A (M3EX-2) following 24 mo storage. The apparent softening at the bondline in the forward chamber at 18 mo is not supported by mechanical or chemical data at 24 months. Data indicate aging behavior follows expected trend lines for Phillips CTPB propellant (Page 43).

Plug samples have been removed from the forward, mid-barrel, and aft regions of Plug Motor 1976A (AA21480) following 110 mo aging. Mechanical properties data indicate significant difference in both propellant and bond properties among sample locations (Page 52). Propellant is harder and bond

I.A. Propellant-Liner-Insulation (Cont)

strength is greater for material from the mid-barrel. Differences are not apparent in results of chemical testing.

NDT On-Surface testing of Plug Motor 1984A revealed that the initial modulus at age 24 mo was 6.2 to 22.6% greater than when this motor was tested at 2 mo of age. The greatest increase was in the aft cylinder area.

Although Lot Combination Motor R7-038 was identified as having a low modulus, On-Surface NDT test results show E_0 values well within the 3σ limits of our database for one month old remanufactured motors.

NDT Surface test data were submitted for three motors by Hill AFB personnel. Modulus values for these motors fall within the expected limits when plotted against aged Phillips CTPB motors. Some test locations were not included in the data provided by Hill AFB. Test locations should be those identified in Tester Propellant On-Surface Manual, Paragraph 2 to 14 and Appendix B, Paragraph 2.0.

Eight motors were tested as part of the on-going Ignition Delay Motor program. The IDM excise surface on recent regrain motors has been atypically rough causing the IDM samples to be of less than desired quality. ASPC Manufacturing corrected the problem when processing Motor R8-006. Good quality samples were removed from that motor.

Ignition delay testing of the MSEX-2 Plugged Motor indicates a lower than normal pressurization slope for both the motor and analog sample.

Conditioning of IDM grains at 80% RH prior to firing has been discontinued. Conditioning appears to increase variability in the data and does not represent the PQA firing environment.

I. Summary/Recommendation (Cont)

B. COMPONENTS

1. Igniter Firings

Twenty-five igniters were fired for VECP B-177, and six igniters were fired for Aging and Surveillance. Testing shows little, if any, change of ballistic parameters due to age, and no trend which would limit service life to less than 34 years.

2. TVC and RC Gas Generators

Gas generator firing results will be reported in SAAS-37.

3. LITVC Permeation

TVC tanks T-159 and T-210, equipped with Uniroyal bladders, continue to have permeation rates low enough to ensure adequate Freon for expulsion after 17 years of motor storage.

4. LITVC Tank and Components

Cold gas expulsion testing done in FY 1986 supports the conclusion that no burst disk aging trend exists which would limit TVC burst disk service life to less than 17 years.

LITVC bladder material from Uniroyal tested after up to two years Freon exposure shows no adverse aging trends. This newly requalified source compares well with materials from the same vendor stored and tested for the original Material Compatibility Program.

II. INTRODUCTION

This semiannual report provides results of tests conducted between 1 September 1985 and 15 March 1986 in support of the Aging and Surveillance program for the Minuteman II and III Stage II motors as described in Reference 1.* The primary objectives of the program are to provide assurance that (1) the reliability of the presently deployed motor will not degrade within a projected replacement time of 17 years, and (2) the service life of the remanufactured motor will be equal to or greater than that of the presently deployed motor population.

To simplify both analysis and presentation of ever-increasing aging data, information from similar materials has been combined; remnants, excised samples, and bulk samples from aged motors are treated as a population of materials from motors. Because a motor/carton bias has been identified, data from laboratory samples will be analyzed independently.

Detailed tabulations for samples tested during the report period are presented in Appendices A through D.

This volume also summarizes results of work conducted on two of three plug motors which have been included in the Aging and Surveillance program. Testing incorporates several sample types from each motor (bulk, excise, and through-the-case plugs) to evaluate differences in properties with respect to location or sample type. In addition, analog samples have been prepared from material cast into a late-production motor to assess motor/carton bias. Particular attention is devoted to plug motors in Section VI.C. Where applicable, test results have been incorporated into the Aging and Surveillance database for evaluation with comparable data.

Propellant - Liner - [illegible] problems, thrust vector control [illegible], and [illegible] are reported upon. [illegible] (Materials), Rocket [illegible], Cracks, → Second stage engines; Ignition delay.

*A reference list is included at the end of the text.

II. Introduction (Cont)

A summary of progress to date on the Early Age-Out Program is also included in Section VI.C. An investigation is underway to identify material characteristics or processing variables which may be responsible for the prematurely aged condition noted in several 10- to 14-year-old motors.

III. BACKGROUND

A failure mode involving degradation of SD-851-2 liner was demonstrated during the Minuteman Long Range Service Life Analysis (LRSLA) program. On the basis of studies indicating this degree of degradation could be expected in motors ranging in age from 14 to 17 years, a remanufacture program was initiated in 1978.

Special studies have been conducted since that time to investigate two additional possible failure modes of the propellant-liner-insulation system: ignition delay and grain cracking due to surface hardening of the propellant (References 2 and 3). Although neither study indicated that the present motor replacement schedule (based on degradation of SD-851-2 liner) needed to be accelerated at that time, data are being obtained on a routine basis to monitor both surface hardening and ignition delay as possible age-limiting modes of failure. Results of studies recently conducted to assess effects of low-equilibrium moisture on a remanufactured weathersealed motor are consistent with nominal service life of 17 years (Reference 4).

The current test plan, Reference 1, emphasizes testing of materials representing remanufactured motors. Limited material testing from original-manufacture motors will be continued to provide visibility regarding long-term aging stability and a base against which performance of the remanufactured motor can be measured.

An extensive program to evaluate the aging stability of motor components other than the propellant-liner-insulation system was conducted prior to

III. Background (Cont)

transition of the Aging and Surveillance program to OO-ALC in 1972. This program was continued on a limited basis until 1980, when it was revised to support the Minuteman Remanufacture program. Details of current investigations are described in Reference 1.

IV. SERVICE LIFE ESTIMATE

Information developed during the Long Range Service Life Analysis program identified hydrolytic liner degradation as the primary mechanism leading to failure for the motor. Kinetic projections for service life ranged from 14 to 17 years based on an assumed silo environment of 50% RH at 70°F. Silo conditions were known to vary, however, and installation of weatherseals in Minuteman motors was recommended to eliminate the effects of extreme humidity conditions in the silos: Weatherseals have been installed on Minuteman motors since June 1980. While weatherseals eliminated the extreme humidity conditions, a concern was raised that motors sealed at low humidity conditions may be prone to excessive surface hardening.

Results of the original Surface Hardening Investigation reported in 1980, indicated the service life of the unsealed Minuteman II and III Stage II motors will not be limited by reduction in strain capability at the inner bore prior to the life limit that is based on degradation in strength of the propellant-liner-insulation bond. Service life prediction based on grain cracking indicated a nominal service life of 17 to 20 years with a lower 3σ limit of 13 years (based on a value of 9.2% strain at break).

An additional surface hardening program was initiated in 1984 to investigate effects of low-equilibrium moisture on a weathersealed motor (Reference 4). Results indicated that weathersealing Minuteman motors will not increase the rate of bore surface hardening in the humidity range from 10 to 50% RH,

IV. Service Life Estimate (Cont)

but the presence of the weatherseal does decrease the rate of hydrolytic degradation of the liner (compared with the estimated 50% RH environment at comparable storage temperatures). Propellant surface hardening should now be considered the primary age-limiting factor for weathersealed Stage II motors.

V. SCOPE/STATUS

This report contains information regarding the following program elements for the propellant-liner-insulation system:

- Propellant removed from motors prior to remanufacture (aft end), aged from 2.5 to 222 mo
- Through-the-case samples (plugs) from (a) a remanufactured motor, aged 24 mo; and (b) an original-production motor, aged 110 mo
- NDT examination of propellant and propellant-liner-insulation bond (original and remanufactured motors)
- Ignition delay investigation (original and remanufactured motors)
- Analog carton samples for propellant lot combinations used in the Minuteman Remanufacture program.

Information is also supplied regarding the following motor components:

- LITVC system
- Internal insulation
- Nozzle

A milestone chart for the various program elements tested during the current report period is provided in Figure 1.

VI. TECHNICAL DISCUSSION OF PROPELLANT-LINER-INSULATION SYSTEM

A. MATERIALS FROM MOTORS

1. Introduction

Testing of full-scale motors is currently conducted using material from the following sources:

- Remnants from previously dissected Stage II motors (original production and remanufacture)
- Samples excised from the aft end of
  - OP motors prior to firing
  - Field return motors prior to remanufacture
  - Plug motors
- Bore samples from the aft bore area of selected motors
- Plugs (through-the-case samples) from original and remanufactured motors.

Information is also available for materials excised from remanufactured (new) motors, bulk samples from field-returned motors and remnants from Stage III dissected motors. Testing for these samples was discontinued following baseline evaluation.

a. Remnants

The aging program for ANB-3066 propellant, originally based on laboratory samples stored at various elevated temperatures, was supplemented in 1973 by inclusion of remnants from dissected Minuteman II Stage III motors.* The motor remnants provided information (such as effects of actual storage conditions, geometric considerations, within and between motor variabilities) that was not available from carton samples alone. In addition, properties of materials from dissected motors differed significantly from

*Same propellant-liner-insulation system as Stage II motors.

VI.A. Materials From Motors (Cont)

those of laboratory samples. Initial tangent moduli of aged motor propellant are higher by a factor of two and elongation is correspondingly lower than measured in laboratory samples. The differences between propellant with Phillips and GTR prepolymers were first noted in data from dissected motors.

Limited testing of materials from original manufacture motors (Stage II only) will be continued to provide information regarding long-term aging stability. Testing of remnants from four dissected remanufactured motors is planned.

b. Excised Samples

A total of 24 excised samples of the propellant-liner-insulation system have been removed from the aft ends of Stage II OP motors. The samples were removed from motors at Hill Air Force Base prior to firing at AEDC. Data from these samples, tested at Aerojet to evaluate the mechanical and chemical properties of propellant, liner, and insulation prior to firing of the motor, have been combined with similar data from other motors and motor remnants to evaluate aging trends in mechanical and chemical properties. Emphasis has since been placed on performance of remanufactured motors; testing of samples excised from remanufactured OP motors will continue.

To gain more information about motor-to-motor variability of aged Minuteman motors, a program was initiated in 1980 to visually examine a large number of motors being returned for remanufacture and remove samples of the propellant and propellant-liner-insulation system from approximately 6 mo each year. These samples currently include excised samples from the aft end of the motor and a sample from the forward end of the motor to evaluate ignitability. These excised samples, combined with samples from earlier aging programs, contribute to a population of 113 samples excised from full-scale motors ranging in age from 4 to 18.5 years.

VI.A. Materials From Motors (Cont)

c. Bulk (Bore) Samples

In addition to samples excised from the aft end, bulk samples have now been removed from the aft portion of the cylindrical bore section of 25 motors returned for remanufacture. Testing of the bulk propellant has contributed to a database for pertinent structural properties of propellant from aged motors as well as established a correlation between properties of the bulk sample and excised samples from the aft end of the motor. Sufficient data now exist to provide a statistically significant bulk/excised correlation; therefore, routine testing of bulk samples has been discontinued. A 1/3-size "bore" sample has been incorporated into the plug motor test plan to assess effects of aging in the critical bore location. Use of this smaller sample will leave ample material for future sampling.

d. Plugged Motors

The plugged motor concept has been included in the revised test plan Three full-scale motors of various vintages (manufactured in 1976, 1984, or 1986) will be stored in a carefully monitored environment. Periodic sampling (by removing "plugs" including case, insulation, liner, and propellant) permits evaluation of aging trends in a realistic stress/strain environment without the complication of motor-to-motor variability. In addition, testing of laboratory samples manufactured and stored with the motor provides information regarding motor/carton bias in properties. This information will greatly enhance the value of the economical carton sample in assessing aging behavior of the propellant-liner-insulation system.

e. Dissection Motors

Four remanufactured (weathersealed) motors, ranging in age from 4 to 9 years, will be dissected over an 11-year period to assess effects

VI.A. Materials From Motors (Cont)

of aging on production materials stored under actual environmental and structural loading conditions. Critical areas for evaluation include the forward bore and Y-joint areas, aft Y-joint area, and forward and aft boots. Remnants will be tested to evaluate effect of aging as well as provide comparison among motors of various years of manufacture. Motor AA22050, cast in 1980, was dissected in 1985; a 1984-vintage motor is scheduled for dissection in 1988.

2. Scope/Status

The Aging and Surveillance program currently includes remnants from five Stage II motors.* Remnants are tested at regularly scheduled intervals; no remnants were tested this report period. Remnants from Motors QT-11 and AA20587 are scheduled for testing during the next report period.

This report includes test results for samples excised from the following aged motors prior to remanufacture:

Motor	Lot Combo/CTPB	Age at Test, mo	Cast Date
AA20887	45/Phillips	170	July 1971
AA21051	52/GTR	161	October 1972
AA21434	64/Phillips	122	September 1975

Motors AA21051 and AA21434 were returned for remanufacture ahead of schedule due to excessive boot gap and liner degradation. To date, 11 motors have been identified with a prematurely aged condition. Suspect motors have been flagged for sampling to evaluate condition of the motors as

*One remanufactured motor: AA22050, cast 7/80.
Four original-production motors: QT-11, AA20013, AA20587, AA20846; cast between 1964 and 1971.

VI.A. Materials From Motors (Cont)

part of an investigation to identify materials or processing variables which may contribute to early age-out.*

This report also includes a summary of data for samples removed from plug Motor MSEX-2 at 24 mo and Motor AA21480 at 110 mo (initial sampling). Results of testing conducted on plugs, excise, bore samples, and analog cartons are presented in Section VI.C.1. Where applicable, data from plug motors have been combined with results from other full-scale motors.

3. Mechanical and Chemical Properties

a. Propellant

Bulk Propellant

Bulk propellant from motors was not scheduled for testing this report period. Remnants from Motors QT-11 and AA20587 will be tested in July and September 1986, respectively.

Gradients from the Bore and Bondline

Uniaxial Tensile Properties - Grain cracking resulting from propellant surface hardening has been identified as a potential mode of failure for the Minuteman propellant-liner-insulation system (Reference 2). As a result, gradients in uniaxial tensile properties as a function of distance from the bore surface were evaluated at 77°F, 1.0 min^{-1} for materials from motors tested during the current report period. Results have been added to plots and tabulations prepared to assess the effect of aging for propellant adjacent to the bore (0.1, 0.2, 0.5, and 1.0 in. from bore, Figures 2 and 3). Motors AA20887, AA21051, AA21434, AA21480, and MSEX-2, ranging in age from

**Results for Motors AA21049 and AA21321 are presented in SAAS-33 and SAAS-34, respectively.

VI.A. Materials From Motors (Cont)

2.5 to 170 mo, have been included. In general, data show good agreement with previously established trend lines: propellant formulated with GTR CTPB shows little change with extended storage, while propellant formulated with Phillips CTPB exhibits significant hardening near the bore with age. Hardening, indicated by an increase in modulus and decrease in strain capability, is attributed to increased crosslinking resulting from diffusion of oxygen into the propellant. Iron contamination in Phillips CTPB is known to increase the rate of oxidative crosslinking in propellant (Reference 2).

Uniaxial tensile properties near the bore for early ageout Motors AA21051 (GTR) and AA21434 (Phillips) are within the range of values for comparably aged motors. Increase in modulus and decrease in strain capability for Motor MSEX-2 from 2.5 to 24 mo is attributed to expected postcure of the propellant which occurs in the first 36 mo of motor life. Data are tabulated in Appendix A.

Stress Relaxation - Gradients in response properties as a function of distance from the bondline interface were measured at 77°F with 2.0% applied strain for materials removed from all motors tested during the current report period. Data are tabulated in Appendix A and shown graphically in Figure 4. This plot (relaxation modulus as a function of storage time for 113 excised samples) is applicable to tests conducted with 2.0% applied strain; results from previous tests (conducted with 0.5% applied strain) have been adjusted using equations described in SAAS 33.

In general, test results at 1.0 in. from the bondline continue to indicate differences between Phillips and GTR propellant, with GTR propellants exhibiting little of the hardening associated with aged Phillips propellants. At 2.0 in. from the bondline, aging behavior is not statistically different between Phillips and GTR propellants: hardening noted at 1.0 in. is not apparent for Phillips propellants (Figure 5). It is likely that hardening at the bondline is related to location of the excised sample (Figure

VI.A. Materials From Motors (Cont)

6). The sampled bondline area in an excise sample lies in close proximity to the bore surface. As a result, propellant in that area experiences moisture and oxygen diffusion both from the bore surface and through the aft boot (lesser degree). Propellant from case-bonded samples (remnants, plugs) does not undergo the degree of hardening at the bondline noted in excise samples.

At the bondline interface, propellant softening is related to degree of liner degradation. In motors where liner has degraded significantly (Motor AA21051, for example), propellant immediately adjacent to the bondline exhibits reduced relaxation modulus in that region.

Chemical Evaluation of Propellant by FTIR (Transmission Spectra of Chloroform Extracts) - No chemical evaluation of propellant from motors was scheduled during the current report period.

b. Propellant-Liner-Insulation Bond

Bond tensile strength of samples excised from the aft ends of field-returned motors has been routinely measured to qualitatively evaluate the effects of aging on the bond capability of the system. (A small bond specimen, 1.0 x 1.0 x 0.5 in., tested at a strain rate of 1.0 min^{-1} was selected as a convenient method to monitor bond strength f... ised material during the LRSLA program.)

Measurements of bond tensile strength for excised samples tested this report period have been added to a population of 113 samples (Figure 7). With the addition of these samples, measurements of bond tensile strength continue to indicate that significant liner degradation has occurred in the aft boot area after 17 years ($\sim$200 mo) storage. Bond strengths of Motor AA21434, returned to ASPC at 122 mo due to excessive liner degradation, are below average but within the range of values for comparably aged motors

VI.A. Materials From Motors (Cont)

Strengths for Motor AA21051, aged 161 mo, are the lowest seen to date (average of 11 psi, ranging from 3 to 24 psi). Liner from Motor AA21051, prepared from Liner Lot L_f, was severely degraded with an abnormal pink color. Liner Lot L_f was used in 7 of the 11 motors rejected at 00-ALC. The rejected motors are from a total of 56 motors inspected at 00-ALC.

For severely degraded liner (<20 psi), bond strength measured in a constant rate test at 1.0 min^{-1}, does not relate to liner condition. Chemical testing can provide a better indication of liner condition for old motors (SAAS-33).

c. SD-851-2 Liner

Chemical test results for liner from motors tested during the current report period are shown in the following table:

Motor SN	Age, mo	Swelling Ratio	Gel-filler Fraction
MSEX-2*	24	1.89	0.613
AA21480*	110	1.89	0.454
AA21434	122	2.28	0.273
AA21051	161	>2.5	0.130
AA20887	170	>2.5	0.260

*Excised from Plug Motors

That SD-851-2 liner proceeds through an initial postcure reaction followed by a hydrolytic degradation reaction is well established. Testing of aged motors indicates the presence of degraded liner. The extent of degradation depends on storage environment as well as age.

VI.A. Materials From Motors (Cont)

The extent of degradation in the liners from Motors MSEX-2, AA21480, and AA20887 is consistent with accumulated motor data for gel-filler fraction based on age. The liners from Motors AA21434 and AA21051 are more degraded than expected for the ages of the motors. Figure 8 shows the excised sample data and the kinetic projection curve for gel-filler fraction at 70°F and 50% RH (unsealed motors). The predicted curve is derived from the kinetic projection for bond tensile strength which was calculated during the LRSLA program.

The two early ageout motors with most severe liner degradation, AA21051 and AA21434, were rejected at Hill AFB from operational use due to premature aging based on visual inspection. Three liner lots (Lf, Sq, and Zs) have been found in the group of motors identified at Hill AFB as prematurely aged. Motor AA21051 has liner from Lot Lf and Motor AA21434 has liner from Lot Zs*. Motor AA21434 is the first motor tested at ASPC from liner Lot Zs*. For a discussion of early ageout motors, see Section VI.C.2.

Motor excised sample data are presented in Appendix A.

d. V-45 Insulation

Shrinkage of the motor insulation in the booted area is a major contributing factor to potential motor failure and is a direct result of net plasticizer loss. To monitor the aging behavior of the insulation, response properties of V-45 insulation for motors tested during the report period were evaluated by stress relaxation tests conducted at 77°F with 2.0% applied strain. Values for relaxation modulus at 1 min, E_{r_1}, are graphically presented in Figure 9 with results for samples excised from 113 motors tested after storage times ranging to 222 months.

In general, data for motors tested this report period show good agreement with established trend lines. Wide sample variability among

VI.A. Materials From Motors (Cont)

113 motors continues to be evident for properties of V-45 insulation. Relaxation modulus for insulation from Motor MSEX-2 increased from 1,275 to 1,774 psi with 24-mo storage (39% increase vs an expected increase of ~5%). The greater than expected increase in modulus may be due to variability inherent in the material itself (orientation effects). Data at 24 mo approximate predicted values for modulus for the population.

The chemical testing conducted on V-45 insulation consists of gel-filler fraction and weight % DOP. Data from the motors tested in the current report period are listed in the following table:

Motor SN	Age, mo	Gel-filler Fraction	% DOP
MSEX-2*	24	0.856	3.40
AA21480*	110	0.890	1.67
AA21434	122	0.881	1.60
AA21051	161	0.907	1.68
AA20887	170	0.889	0.93

*Excised from Plug Motor

The test results from the five motors are consistent with previously tested motors. Figure 10 shows the aging trends of gel-filler fraction and weight % DOP. The increases in gel-filler fraction with time represents the net effect of DOP loss, Oronite-6 gain (from the propellant), and moisture gain in the insulation.

The migration of DOP from the insulation to the liner/propellant is a diffusion process dependent on time and temperature. Since DOP concentration for the two early ageout motors (AA21051 and AA21434) is consistent with the projected loss based on age, early ageout is considered to be primarily a function of liner hydrolytic degradation.

VI.A. Materials From Motors (Cont)

Motor excised sample data are presented in Appendix A.

4. NDT Examination of Motors

a. Visual Inspection

The objective of visually inspecting Minuteman Stage II motors from the Motor Remanufacture Program is to determine long-term aging effects on the propellant, liner, and insulation. Bond system quality is based on boot gap and boot lifting from the propellant on the forward and aft ends of the grain. In the forward end, measurement of nipple lifting and movement with respect to the propellant is made at the 0-deg location. On the aft end, boot lifting and movement of the boot with respect to the propellant are measured at the 180 deg location. The 0- and 180-deg locations are used because they typically are the areas with the greatest lifting and boot movement.

Overall propellant quality is estimated on the motor by measuring propellant slump and by visual observation of cracks, voids, discoloration, and AP on the surface of the propellant. In addition, Shore A is measured at the forward, bore, and aft sections of the grain to determine propellant surface hardness. From these findings, general quality of the motor grain is classified as fair, poor, or very poor. A "good" grain condition would be as-manufactured (zero age). A chart showing how the ratings are derived is presented in Appendix A, Figure A-7.

Since the last report period, the following 24 motors were visually inspected.

VI.A. Materials From Motors (Cont)

Phillips		GTR	
20598	20820	20555	20953
20602	20818	20593	20957
20614	20894	20612	21051
20630	20924	20687	21067
20645	20932	20750	
20760	21434	20786	
20801		20855	

A visual inspection summary for these motors is located in Appendix A, Figure A-8. A visual inspection for all motors inspected to date is located in Appendix A, Figure A-9.

Differences between motors manufactured with GTR and Phillips CTPB continues to be small. Motor rating by CTPB manufacturer is shown below:

	GTR	Phillips	Pooled (Philips and GTR)
Fair	48%	42%	46%
Poor	32%	44%	37%
Very Poor	20%	14%	17%

Motors rated "Fair" would be considered acceptable for field use, and motors rated "Poor" or "Very Poor" would be considered aged out.

The visual inspection database at ASPC has been augmented by visual observations at OO-ALC, which is usually restricted to observations through the igniter boss because of motor disassembly limitations. These data are an important addition to the present database because they represent motors from a younger population increasing the range of motor ages.

Motors 21051, 21067, and 21434 were sent to ASPC this report period, since they failed to meet ageout criteria when inspected by OO-ALC.

VI.A. Materials From Motors (Cont)

These motors were 10.2 to 13.4-yr old at the time of ASPC visual inspection and were considered to have aged-out prematurely. These motors all had a very poor bond system, but all other inspection parameters were in fair condition. The ASPC inspection results of these motors is included in the visual inspection report in Appendix A, Figure A-8. See Section VI.C.2. of this report for more about the early age-out investigation.

Forward nipple lifting at the zero degree motor azimuth was observed on one of the 24 motors inspected this report period. Nipple lifting was 0.03 in. for this motor. Ten of the 24 motors had forward nipple unbonds but no measurable lifting; three of these ten were early age-out motors. Figure 11 shows a histogram of forward nipple lifting of all motors inspected to date except for Motor AA20502. Forward lifting of this motor was eliminated from the database since its original inspection report is erroneous. The distribution is one-sided normal and has an upper 3σ limit of 0.09 in. Seven motors were reported to have forward lifting greater than this limit and are considered to be outliers. Possible explanations for these high data are:

- Measurement inaccuracy
- Incorrect recording
- Data is real and was reported correctly

It is likely that these large data (>0.09 in.) are the result of some combination of all three possibilities and will be treated as questionable for future analysis.

b. Propellant Properties (On-Surface, Shore A)

Two washout, two lot combo, two PQA and one plug motor were tested for On-Surface and Shore A hardness. The test results are summarized in Appendix A of this report. Data from three Hill AFB tested motors are also summarized in Appendix A.

VI.A. Materials From Motors (Cont)

A graphic presentation of E_0 (initial modulus) at seven axial locations in the motor is provided in Figures 12 through 15. The $\pm$ 3σ limits vary somewhat for motors in the same category (Washout, Phillips CTPB, GTR CTPB, Remanufactured) because data values used to determine $\pm$ σ limits did not include those of the motor tested. This was done to prevent the motor from being forced within the limits of a small database population. A permanent database will be established when the sample population in each category equals 20 motors.

Washout motors AA21434 and AA20887 initial modulus values fall well within the $\pm$ 3σ limits, Figure 12.

Lot Combo Motors R8-006 and R7-038 were well within the 3σ limits for one month old regrain motors. R7-038 was identified as a low modulus motor; the forward readings were somewhat low but all values are within expected limits, Figure 13.

The surface hardness values for PQA 6-111 and PQA 6-110, Figure 14, are typical for one month old remanufactured motors.

Plug Motor 1984A at 24 mo has aged sufficiently to be included in the database for washout motors, Figure 15A. The On-Surface modulus values have increased 6 to 23% at the axial test locations over the last 22 mo, Figure 16. This shift in the surface E_0 is in general agreement with the bulk sample data.

Data from Hill AFB tested Motors AA22114, AA22272, and AA22304 are shown in Figure 15B,C,D.

VI.A. Materials From Motors (Cont)

c. Ignitability (IDM, SEM)

Ignitability testing is performed on selected old and regrain Minuteman Stage II (MM II) motors. Propellant is excised from the forward fin slots and tested using the Ignition Delay Motor (IDM) and Scanning Electron Microscope (SEM). SEM analysis reveals surface features which may affect ignitability. The IDM is a small ballistic model designed to dynamically simulate the ignition transients and flame propagation of the Minuteman Stage II motor.

During this reporting period two washout motors (AA20887 and AA21434), two lot combination motors (R7-017 and R8-006), two Production Quality Assurance motors (R7-036 and R8-003) and two plugged motor samples (from MSEX-2 and one of its analogs) were tested. Ignitability testing and SEM results for these motors are reported in the testing summary in Appendix A of this report.

The data from motors tested during this period exhibit great variability. The Regrain motors, both PQA and Lot Combo, show the greatest range. PQA 6-110 and Lot Combo motor R7-017 produced relatively low ignitability indices while PQA 6-111 and Lot Combo R8-006 produced ignitability indices close to the mean. It seems unreasonable that this much spread exists in new motors. Two factors are readily identifiable as potentially affecting the apparent ignition delay. The first, documented previously in SAAS-34 and -35, is the rough condition of the upper fin slots where IDM samples are excised. The problem has been identified by ASPC Manufacturing as a processing finish in the preparation of the fin cores. Changes in preparing the fins for release have been instituted and, judging from samples taken from R8-006, appear to have solved the "roughness" problem.

The second factor in producing variable data may be the high humidity (80% RH) conditioning of the IDM grain 24 hr prior to firing. This

VI.A. Materials From Motors (Cont)

humidity conditioning was used in the original studies to attempt to produce a "worst-case" scenario. The conditioning interval is difficult to control because of scheduling demands at the burning rate laboratory. The effects of overconditioning (i.e., exposed to 80% RH for longer than 24 hr) and IDM performance has not been thoroughly investigated but a quick look at the data of IDMs known to be overconditioned indicates that ignition performance decreases. It is known that pitted, scuffed, and/or AP coated surfaces are more humidity sensitive. In addition, work with IDMs fabricated from Peacekeeper propellant (ANB-3600) where IDM grains were and were not exposed to the 80% RH prefire conditioning demonstrated a greater range when conditioned. The 80% RH conditioning scenario does not reflect the normal firing condition of the PQA motors and may increase the scatter of ignitability data. The IDM performance attempts to directly correlate to PQA ignition performance. Therefore, the decision to delete the IDM prefire conditioning has been made.

It is anticipated that the acquisition of good quality samples and a more realistic firing environment will eliminate some of the data variability. The excise tooling has also been adjusted to provide more uniform sample quality. The adjustments consisted of reshimming the excise tooling to compensate for wear and provide more positive control of the excise knives.

Two IDMs were tested as part of the plugged motor program. One IDM was configured from propellant excised from MSEX-2 and one was configured from an MSEX-2 analog carton. Both samples were taken from released propellant surfaces. Two factors are evident from the firing data. First, there is a variance between the analog carton sample and the motor excise samples. The lower ignitability values appear to be consistent with the ignitability index produced by the first sample excised from MSEX-2. No reason for the lower performance is apparent. Further investigation into the propellant properties is warranted.

VI.A. Materials From Motors (Cont)

Since IDM test results are used to predict full-scale Minuteman Stage II ignition delays, a prefire prediction was issued for PQA 6-109 in this reporting period because the SEM work-up was pending at the cut-off date for SAAS-35 reporting.

The prefire report for PQA 6-109 indicated a normal firing. The prefire report for PQA 6-110 indicated a very low ignitability slope and the ignition delay prediction is considered anomalous since SEM analysis did not support the low performance. Sample quality and prefire conditioning are suspect.

The prefire report for PQA 6-111 (R8-003) is pending SEM evaluation although the IDM data indicates a normal (0.104 sec) ignition delay. PQA motor firings are on "hold" pending the resolution of facility problems at AEDC.

B. LABORATORY SAMPLES

1. Introduction

Analog carton samples prepared as shown in Figure 17 are used to monitor the aging behavior of ANB-3066 propellant used in the Minuteman Remanufacture program. The sample, designed to simulate the surface-to-free volume ratio in the bore of the Minuteman Stage II motor, is sealed to represent a motor with a weatherseal in place. The bondline is designed to simulate the aft booted area of the motor, where aging effects are known to be greatest. Samples representing each propellant lot combination are tested after designated periods of storage at 80, 110, and 135°F to provide assurance that no unexpected variation in stability occurs with changes in materials or processing.

VI.B. Laboratory Samples (Cont)

To ensure that propellant representative of full-scale motors is being monitored, analog samples are now prepared from propellant batches used in the sixth motor cast for each lot combination (as opposed to use of qualification (DW) batches). Samples from Lot Combinations 85A, 85B, 86A, 87B, 88D, and 89A have been cast from motor batches.

Although previous studies have indicated significant differences exist between properties of propellant cast into motors and properties for laboratory samples, it is expected that aging trends will be similar.

Analog testing at selected intervals (8 to 16 mo) provides early warning of impending problems in motors cast from a particular lot combination.

Testing is complete for Lot Combinations 74 through 85B. Samples obtained from Lot Combinations 86A through 89A were tested after storage at the following conditions:

Lot	80°F		110°F	135°F
Combo	Control	12 mo	16 mo	8 mo
86A	X	X	X	X
87B	X	X	X	X
88D	X			X
89A	X			

VI.B. Laboratory Samples (Cont)

2. Mechanical and Chemical Properties

a. Propellant

Bulk Propellant

Uniaxial Tensile Properties - Uniaxial tensile properties of control and aged samples were measured at 0, 40, 77, and 110°F at a strain rate of 0.74 min^{-1}. Tests conducted at 150°F, 0.0074 min^{-1} and 77°F, 100 min^{-1} at 1,650 psig were added in the revised test plan to measure performance of the propellant at test conditions related to operational storage and firing loads. Test results from samples tested this report period are tabulated in Appendix B.*

Values of uniaxial tensile properties measured at 77°F, 0.74 min^{-1} for unaged samples from 16 lot combinations have been plotted in control chart format in Figure 18. Data indicate wide variability in modulus and strength for unaged propellant. Moduli of samples from 86A, 87B, and 88D are among the highest to date. On the basis of past experience, it is expected that moduli for these lot combinations will remain high with aging.

Data measured at 77°F, 0.74 min^{-1} have been combined to assess aging behavior of the total population at several aging conditions. Although additional data are available for unaged samples, the sample size for the unaged population was limited to results from Lot Combinations 76 through 87B to provide a direct comparison in properties between the aged and unaged populations (i.e., for the same batches). The cumulative frequency distribution of initial tangent modulus for control and aged populations is plotted

*Appendix B includes results of testing conducted on Lot Combinations 85A through 89A. Results for Lot Combinations 74 through 84 are available in SAAS-33.

VI.B. Laboratory Samples (Cont)

in Figure 19. This approach is useful in estimating the mean, variability, and normality of the population and the approximate magnitude of change in properties with aging.

The data have been plotted on logarithmic paper as a means of normalizing variability in modulus on a basis of percentage increase. The roughly parallel slopes of the data for the unaged and samples aged at elevated temperatures suggest little change in percent variability with aging.

The irregular slope of the cumulative frequency curve for the samples aged at 80°F for 12 mo indicates greater variability in properties at that condition. This increased variability suggests that at 80° F, expected propellant hardening related to postcure is not complete following 12-mo storage. Following storage at high temperatures, variability in properties goes down as samples reach the same level of cure (indicated by shallower slope for 110 and 135°F aging in Figure 19). High variability at 80°F indicates that factors in addition to elapsed time can influence the rate of cure for ANB-3066 propellant. Work will continue to evaluate effects of formulation variables and materials on aging behavior for propellant lot combinations.

In general, the lot combinations tend to age at approximately the same rate; that is, a lot combination for which modulus is initially the highest of the population will be found in the high range of aged samples. (Exceptions for Lot Combinations 77 and 78 were noted in the last report.) Propellant for Lot Combination 87B, included this report period, behaves as expected in comparison with other batches (initially high modulus stays high with aging). Modulus for Lot Combination 86A is high initially, but approaches average values with aging.

VI.B. Laboratory Samples (Cont)

Data for strength and strain capability were treated using the approach described for modulus. The average (median) increase in properties for the population (12 lot combinations) following storage at several aging conditions is shown below:

	Normalized Properties (Aged/Unaged)			
Aging Condition	σ_m	ϵ_m	ϵ_b	E_o
Unaged (Median)	95	35	52	464
Unaged	1.00	1.00	1.00	1.00
12 mo at 80°F	1.24	0.74	0.68	1.43
16 mo at 110°F	1.49	0.59	0.48	2.18
8 mo at 135°F	1.60	0.55	0.43	2.52

As expected, most severe changes in properties occur at elevated storage temperatures. On the basis of kinetic evaluation of the data, 8 mo storage at 135°F is approximately equal to 52 mo at 80°F; 16 mo at 110°F is approximately equivalent to 46 mo at 80°F.

Stress Relaxation - Data for relaxation moduli (tests conducted at 77°F, 2.0% applied strain) of control and aged propellant samples are in agreement with hardening trends noted for uniaxial tensile properties.

Data were treated using the approach described for uniaxial tensile results (cumulative frequency distributions). The average (median) increase in relaxation modulus for the population (Lot Combinations 76 through 87B) following storage at several aging conditions is shown in the following table:

VI.B. Laboratory Samples (Cont)

Aging Conditions	Median E_{r_1}	Normalized E_{r_1} (Aged/Unaged)
Unaged	274	1.00
12 mo at 80°F	460	1.68
16 mo at 110°F	695	2.54
8 mo at 135°F	820	3.00

A comparison of normalized relaxation modulus with normalized initial tangent modulus (Section VI.B.2.a.) indicates a greater change in response properties with aging than in uniaxial tensile properties for samples stored at all conditions. Data are presented in Appendix B.

Gradients from the Bore and Bondline

Uniaxial Tensile Properties - Grain cracking due to propellant surface hardening has been identified as a potential failure mode for the Minuteman propellant-liner-insulation system (Reference 2). As a result, the gradients in uniaxial tensile properties as a function of distance from the simulated bore surface are routinely measured using mini tensile specimens (0.1 in. thickness, 1.0 in. gage length).

Effect of aging on strain capability at the bore surface for samples from 16 lot combinations (Lot Combinations 76 through 89A) is presented in Figure 20. The most pronounced change in properties with aging (increased strength and modulus, decreased strain capability) occurs at the simulated bore surface (0 to 2.0 in. from bore surface). As expected, storage at 135°F produces most severe decreases in strain capability as shown on the following table:

VI.B. Laboratory Samples (Cont)

Storage Condition	No. Lot Combos	Average Ratio of ϵ_m* 0.1 in. From Bore Surface	(Aged/Unaged) 2.0 in. From Bore Surface
Unaged (ϵ_m, Median)	16	20.8%	28.8%
Unaged	16	1.00	1.00
12 mo at 80°F	12	0.86	0.83
16 mo at 110°F	12	0.65	0.83
8 mo at 135°F	15	0.45	0.67

At distances greater than 2.0 in. from the bore surface, the initial gradient in properties tends to be retained as the propellant is aged.

Strain capability near the bore for unaged propellant from Lot Combination 87B is the lowest seen to date. Values are within the range of previously tested samples following storage at 135°F.

<u>Stress Relaxation</u> - The gradient in relaxation moduli as a function of distance from the bondline is measured in tests conducted at 77°F with 2.0% applied strain. The relaxation modulus is important in assessing stresses at the bondline.

Data from 16 lot combinations indicate the presence of a hardened layer in unaged samples at 0.1 in. from the bondline interface (Figure 21). With aging at elevated temperatures, the propellant at 0.1 in. shows some softening, which as been attributed to migration and subsequent degradation of aziridines from SD-851-2 liner. Migration of plasticizers from the insulation may also contribute to propellant softening. Propellant at distances greater than 0.1 in. from the bondline interface continues to harden with age. As noted for propellant near the bore surface, hardening is due to oxidative crosslinking resulting from oxygen migration into the propellant.

*Strain at nominal stress, ϵ_m

VI.B. Laboratory Samples (Cont)

Due to the barrier effect of the V-45 insulation, hardening proceeds at a slower rate than near the bore.

Oxygen migration into propellant near the bondline has been confirmed by examination under ultraviolet light. Aged ANB-3066 propellant typically exhibits a color difference under ultraviolet light in areas of low antioxidant concentration (Reference 5). In an analog aged 12 months at 80°F, (Lot Combination 88D), a band was noted to a depth of approximately 3/4 in. (versus approximately 7/8 to 1 in. at the bore). This band has been noted at the bondline in aged analogs regardless of storage condition, as well as in samples excised from the aft end of motors. It is not present in case-bonded samples (motor plugs or remnants), where oxygen is not available for crosslinking. Hardening at the bondline should, therefore, be greatest in the booted areas of the motor.

Chemical Evaluation of Propellant by FTIR - Chemical testing of propellant consists of FTIR transmission spectra of chloroform extracts for gradients from the simulated bore and bondline surfaces of the analog samples. The absorbance of the trans double bond peak at 970 WN (normalized to initial weight) exhibits changes typical of all CTPB peaks and is indicative of the amount of extractable CTPB, which decreases as the crosslink density of the propellant increases. A complete discussion of FTIR capabilities is presented in SAAS-34. FTIR data are presented in Appendix B.

The wide range of extractable CTPB observed from the various unaged lot combinations is attributable to the differences in the degree of postcure. After aging 12 mo at 80°F, most of the postcure reaction is completed and the range of extractable CTPB observed between the various lot combinations has narrowed. The effects of aging at both the bore and bondline surfaces are evaluated by comparing the test results of samples after accelerated aging (16 mo at 110°F and 8 mo at 135°F) and the samples aged 12 mo at 80°F.

VI.B. Laboratory Samples (Cont)

Gradient from the Bore - Bore surface hardening is observed in analog cartons. The degree and depth of hardening depends on temperature and time. The mechanism for bore surface hardening is diffusion of oxygen into the propellant followed by oxidative crosslinking reactions. The activation energy of the crosslinking reaction is higher than the activation energy of diffusion. Consequently, propellant exposed to higher temperatures undergoes the crosslinking reaction faster, limiting the depth of diffusion of oxygen. Conversely, propellant exposed to lower temperatures crosslinks slower and allows oxygen to diffuse to a greater depth from the bore surface.

The amount of extractable CTPB near the bore surface, measured by the absorbance of the 970 WN peak, is indicative of the extent of oxidative crosslinking. Comparison of test results between the two accelerated aging conditions and 12 mo aging at 80°F is shown in Figure 22. The aging trends are (1) a slight decrease in the amount of extractable CTPB after 16 mo at 110°F to a depth of at least 0.5 in. and (2) a greater decrease in the amount of extractable CTPB after 8 mo at 135°F to a depth of 0.3 in. Hardening to similar depths at the two accelerated aging conditions is observed for mechanical properties.

Gradient from the Bondline - The propellant adjacent to the liner is highly crosslinked in unaged cartons and in cartons aged 12 mo at 80°F. The initial hardening at the bondline results from the migration and subsequent reaction of the liner aziridines in the propellant. Upon accelerated aging, two competing reactions are occurring (1) the propellant near the bondline (farther than 0.1 in.) oxidatively crosslinks as a result of oxygen diffusing through the insulation/liner into the propellant. The depth of hardening depends on time and temperature (similar to bore surface hardening), and (2) the propellant immediately adjacent to the liner degrades. This degradation at the bondline can be attributed to one of the liner aziridines, TMAT, which has a lower activation energy for the degradation reactions (thermal and hydrolytic) compared to the aziridine (BITA) in the propellant.

VI.B. Laboratory Samples (Cont)

TMAT is thus more susceptible to degradation. The extent of softening observed at the bondline interface may depend on the relative amounts of both TMAT and moisture at the interface.

The amount of extractable CTPB near the bondline reflects the two competing reactions, oxidative crosslinking and degradation of TMAT. At depths greater than 0.1 in. from the bondline, the amount of extractable CTPB at the three aging conditions is similar to the amount observed near the bore surface (indicative of oxidative crosslinking). Comparison of the amount of extractable CTPB from cartons after 12 mo aging at 80°F to cartons after accelerated aging shows the effects of initial hardening followed by degradation at the bondline interface. After 12 mo, the interface has less extractable CTPB compared to 0.2 in. After accelerated aging, the interface has the same or greater amounts of extractable CTPB compared to 0.2 in., indicative of degradation (see Figure 23). Mechanical properties show similar aging trends near the bondline.

b. Propellant-Liner-Insulation Bond

The effect of aging on the strength of the propellant-liner-insulation bond (ANB-3066/SD-851-2/V-45) has been routinely monitored using constant rate and constant load tests conducted at 77°F. These tests are now supplemented with high rate shear tests conducted at operational conditions (1,000 min^{-1}, 600 psig superimposed pressure) to determine effects of age on bond strength for firing. Although bond strength of the propellant-liner-insulation system is probably not associated with changes in propellant lot combinations, strengths are routinely monitored to provide general information regarding aging behavior of the bond.

Data continue to indicate an initial increase in bond tensile strength due to postcure for samples stored at 80°F (Figure 24). (Data for Lot Combinations 79, 83, and 85B show a slight decrease for both standard and

VI.B. Laboratory Samples (Cont)

mini-sized specimens.) Bond strengths are decreased for samples stored for 24 or 36 mo at 80°F. This decrease is expected, indicated by results of liner degradation studies conducted during the LRSLA program.

Bond tensile strengths decrease following storage at elevated temperatures for all lot combinations during the first year. Additional testing conducted on samples from Lot Combination 76 suggests that bond strength continues to decrease at elevated temperatures following 24-mo storage. Data for all lot combinations are provided in Appendix B.

Change in failure mode with age provides information about the failure mechanism. Unaged bond specimens typically fail between the propellant and liner. As the bondline ages and strengths decrease, the failure occurs in the liner. This failure mode is consistent with the degradation of the liner with age noted in both chemical and bond properties.

Testing using mini-sized specimens (1.0 x 1.0 x 0.5 in.) has been performed in conjunction with standard specimens (1.75 x 1.75 x 1.0 in.). In general, bond tensile strength measured using mini-sized specimens is slightly lower than strengths for standard specimens over the range of data (approximately 40 to 120 psi). Mini-sized specimens are frequently used where sampling material is limited (excised samples, plugs) or to evaluate effects of location in critical areas.

Tests of the propellant-liner-insulation bond have been expanded to include high rate shear tests conducted at operational conditions (tested at 77°F, 1,000 min^{-1}, 600 psig superimposed pressure). Values for unaged analogs from Lot Combinations 85A through 89A range from 220 to 272 psi. With aging, variability in strength increases: Of nine lot combinations for which aging data is available, three show increases and six show decreases in shear strength (Figure 25).

VI.B. Laboratory Samples (Cont)

c. SD-851-2 Liner

Updated data tables for chemical testing of SD-851-2 liner from Lot Combinations 76 to 89A are provided in Appendix B. Chemical testing includes swelling ratio and gel-filler fraction. The gel-filler fraction values reported are corrected for variations in liner thickness. A complete discussion of the correlation of liner thickness and gel-filler fraction is presented in Appendix A of SAAS-34. Current test data from the liners in Lot Combinations 86A, 87B, and 88D follow previously established trends as shown in Figure 26.

d. V-45 Insulation

Results of stress relaxation tests conducted on V-45 insulation used in analogs with different propellant and liner lot combinations continue to indicate somewhat erratic data. Wide variability is probably due to orientation effects in the basic material. Unaged cartons representing Lot Combinations 76 through 89A gave values for relaxation modulus at 1 minute (tested at 77°F, 2.0% applied strain) ranging from 790 to 1,294 psi. Relaxation moduli continue to increase with increasing time for all storage conditions.

VI.B. Laboratory Samples (Cont)

RELAXATION MODULUS CHANGE - (77°F, 2.0% STRAIN, 1 MIN)

Storage Conditions

Lot Combo	E_{r1} at 77°F	12 mo at 80°F	24 mo at 80°F	36 mo at 85°F	16 mo at 110°F	8 mo at 135°F
76	1086	-13	23	26	17	14
77	1033	16			48	35
78	1138	1	17	44	34	42
79	792	14	81		60	79
80A	870	20	-5		63	31
81A	810	-29				57
82E	990				32	43
83	874	26			84	42
84	790	17			73	37
85B	847	48			77	81
86	990					67
86A	1215	36			16	19
87B	1088	15			12	63
88D	1294					24
89A	1162					

Chemical testing of V-45 insulation includes swelling ratio, gel-filler fraction, weight % DOP, weight % H_2O, Shore A hardness, and density. Updated data tables for chemical testing of insulation from Lot Combinations 76 to 89A are provided in Appendix B. Current test data from Lot Combinations 86A and 87B follow previously established trends as shown in Figure 27. The swelling ratio and density values for the insulation from Lot Combination 88D at the first two test intervals are anomalous. Future testing of insulation from Lot 88D will be examined for continued anomalous behavior.

Anomalous behavior in chemical properties for material from Lot Combination 88D analogs is not apparent in relaxation properties.

VI.B. Laboratory Samples (Cont)

The wide range of swelling ratio values between lot combinations is due to the anisotropic nature of V-45 insulation. Swelling ratio depends on the orientation of the test specimen. Orientation of the carton insulation relative to the insulation calendaring direction is unknown.

C. SPECIAL TOPICS

1. Plug Motors

a. Introduction

The concept of a plugged motor has been included in the revised test plan, Reference 1. Periodic sampling of full-scale motors, stored under carefully monitored conditions, permits evaluation of aging trends in a realistic stress/strain environment without the complication of motor-to-motor variability. Methods have been developed to remove through-the-case samples (plugs include case, insulation, liner, and propellant) while retaining the structural integrity of the motor for future sampling (SAAS-34).

The program is designed to sample three motors (1976-vintage original manufacture, 1984- and 1986-vintage remanufacture) and evaluate them on a continuing basis for comparison with motors (and remnants of motors) of the same year of manufacture. Plugs from the forward, mid-barrel, and aft chamber areas of each motor are supplemented with tests of excised samples (forward and aft), bore samples, and nondestructive test techniques.

Analog carton samples cast with the same propellant and liner batches used in the 1984 motor (MSEX-2) have been stored with the motor and will be tested in conjunction with the motor plugs at selected intervals to provide a correlation between material properties in the full-scale motor and corresponding properties of small-scale laboratory samples (Figure 28). Knowledge of these relationships will enhance the value of the more economical

VI.C. Special Topics (Cont)

analog samples. No carton samples will be available for propellant cast into Motor AA21480 (1976 vintage) and Motor R7-032 (1986 vintage).

b. Scope/Status

This discussion contains results of testing conducted on plug samples removed from the forward and mid-barrel areas of Motor MSEX-2 following 24-mo storage. In addition, an aft excise sample, aft bore sample, and laboratory sample were tested this report period.

Testing is complete for initial samples removed from Motor AA21480, a 1976-vintage original-manufacture motor. This motor was selected for use as a plug motor to evaluate effects of real-time aging on mechanical properties of late-production materials. Data are available for four plugs, aft excise, and aft bore samples.

Each sample type provides specific information regarding aging behavior of the motor. A brief description of objectives for each sample is provided in Figure 29.

c. Mechanical and Chemical Properties

Motor MSEX-2

Excised Sample - A sample was removed from the aft end of Motor MSEX-2 after 24-mo aging to evaluate aging effects in that area in comparison with previously tested motors. Test results for propellant and bond testing are compared with a population of 113 motors in Section VI.A. Data indicate that aging behavior of Motor MSEX-2 follows expected trend lines for Phillips propellant:

VI.C. Special Topics (Cont)

- Increase in modulus, decrease in strain capability at the bore surface, Figure 3
- Increase in relaxation modulus at the bondline (1.0 in. from interface), Figure 4
- Decrease in bond tensile strength, Figure 7
- Increase in relaxation modulus for V-45 insulation, Figure 8.

For propellant near the bondline and V-45 insulation, relaxation moduli increased at faster rates than expected on the basis of trends for older samples. It is likely that aging behavior may change at various stages of motor life: in analog samples, the greatest degree of change in propellant properties occurs during the first year. The ability to track propellant properties for a given motor (using the plug motor approach) will help define aging behavior throughout its life and increase confidence in service life estimates.

Material from the aft end has hardened with aging to 24 mo for propellant at distances from 0.2 to 2.0 in. from the bondline. At 0.1 in., initial tangent modulus is slightly reduced. Based on testing conducted on a population of 113 excised samples, propellant typically softens adjacent to the bondline as a result of migration and subsequent degradation of species from the liner and insulation. The greater degree of hardening in the aft end in comparison with plug areas (Section VI.C.1.c) is due to availability of oxygen migrating through the permeable aft boot, which increases the rate of crosslinking in that area.

Bore Sample - Uniaxial tensile properties of a sample removed from the aft bore were measured at 77°F, 0.74 min^{-1} and 74 min^{-1} with superimposed pressure. Data indicate expected propellant hardening with aging from 2.5 to 24 mo.

VI.C. Special Topics (Cont)

	77°F, 0.74 min^{-1}				77°F, 74 min^{-1}, 600 psig			
Age, mo	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	σ_m, psi	ε_m, %	ε_b, %	E_o, psi
2.5	128	17	26	1188	442	31	36	2761
24	157	15	20	1607	504	27	28	3710

Gradients in properties from the bore surface were measured using mini-sized specimens. Data for material removed from the aft bore are compared below with values for propellant from the aft end (excise sample). Data indicate significant hardening with aging from 2.5 to 24 mo for both locations. Strain capability in the aft chamber continues to be slightly higher than that in the aft end. Based on testing conducted on 25 bulk samples, strain capability is usually lower in the aft bore area in comparison with the aft end.

	Aft End (Excise)		Aft Chamber (Bore)	
Age, mo	0.1 in.	1.0 in.	0.1 in.	1.0 in.
2.5	14.6	18.4	15.0	20.0
24	12.4	15.2	14.6	16.6

Detailed tabulations are provided in Appendix C.

Plugs - Bulk Propellant - Bulk propellant in plugs removed from the forward and mid-barrel areas of Motor MSEX-2 shows the effects of 6 mo additional aging (24 mo total). Initial tangent modulus and strength, as measured at 77°F, 0.74 min^{-1}, increased slightly at both locations with corresponding decreases in strain capability.

VI.C. Special Topics (Cont)

Sample Location	Forward					Mid-Barrel				
Age, mo	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA
12	138	21	32	1015	57	128	19	32	1227	60
12						129	19	33	1135	
18	135	20	29	1160	61					
24	141	18	27	1220	62	135	16	27	1367	60

Data continue to indicate that propellant in the mid-barrel is slightly harder than material removed from the forward chamber. Propellant properties are known to vary within a motor due to sample location. Differences in properties may be a result of differences in aging behavior among the propellant batches; as discussed previously, no significant differences in initial properties for the batches were apparent on the basis of testing conducted on qualification cartons.

A comparison of propellant properties between plugs and laboratory samples confirms motor/carton bias previously noted for ANB-3066 propellant. Samples from the motor continue to exhibit higher modulus and lower elongation than analog samples.

Property at 77°F, 0.74 min^{-1}	Age, mo	Plug (n = 2)	Analog (n = 1)	Ratio Plug/Analog
σ_m, psi	24	138	128	1.08
ϵ_m, %	24	17.0	23.0	0.74
ϵ_b, %	24	27.2	27.8	0.98
E_o, psi	24	1314	876	1.50

Properties for the laboratory sample are typical of values for analog samples from Lot Combination 76 aged to 24 mo (E_o at 77°F, 0.74 min^{-1} = 884 psi).

VI.C. Special Topics (Cont)

Results of stress relaxation tests conducted at 77°F, 2.0% applied strain support hardening trends noted for uniaxial tensile properties. At 24 mo, relaxation moduli at the forward and -barrel areas are approximately equivalent (in contrast to dif s between areas for uniaxial tensile properties).

Modulus for propellant from the analog sample is slightly lower than values measured for propellant from plugs stored for 24 mo (E_{r_1} = 755 psi versus 789 to 810 psi for material from plugs).

Plugs - Gradient from the Bondline

Uniaxial Tensile Properties - Changes in modulus with aging are of particular concern at the bondline of a motor, where stresses are greatest. As a result, the gradients in uniaxial tensile properties as a function of distance from the bondline interface were measured in plug samples using mini-tensile specimens (0.1 in. thickness, 1.0 in. gage length). Results of testing conducted at 77°F, 1.0 min^{-1} are plotted in Figure 30 in comparison with data from previous test intervals. Softening noted at the bondline at 18 mo is not apparent at 24 mo for plugs. Properties at 24 mo are approximately equivalent to those measured at 12 mo.

Comparable data for 24 mo analogs are included in Figure 30. As noted for data at 12 mo, propellant near the bondline interface (hoop orientation) is considerably harder than that from plug samples (axially oriented) to a depth of approximately 1.0 in. from the interface. Results of previous studies have indicated a considerable effect of specimen orientation on mechanical properties for ANB-3066 propellant (specimens oriented axially exhibit lower modulus and strength, higher elongation than specimens oriented in the hoop direction). It is expected that analog values would be lower if specimens were oriented in the axial direction. It is not currently possible

VI.C. Special Topics (Cont)

to orient specimens from the analog in an axial direction due to configuration of the sample. As noted in the previous section, properties of bulk propellant, as measured using JANNAF specimens, axial orientation, were significantly higher for propellant from motors than that from analogs.

<u>Plugs - Stress Relaxation</u> - Gradients in relaxation moduli as functions of distance from the bondline of plug samples were measured in tests conducted at 77°F with 2.0 applied strain. Data are included in Appendix C and indicate good agreement with gradients noted for uniaxial tensile properties.

<u>Plugs - Chemical Evaluation of Propellant by FTIR</u> - Chemical testing of propellant consists of FTIR transmission spectra of chloroform extracts for gradients from the bondline surfaces of plugged samples from motors. The absorbance of the trans double bond peak at 970 WN (normalized to initial weight) exhibits changes typical of all CTPB peaks and is indicative of the amount of extractable CTPB. The amount of extractable CTPB will decrease as the crosslink density increases. A complete discussion of FTIR capabilities is presented in SAAS-34. FTIR data is presented in Appendix C.

The changes in the amount of extractable CTPB with aging near the bondline reflect changes in the degree of crosslinking in the propellant. The bondline interface (0.025 in. deep) has less extractable CTPB (compared to bulk propellant) due to the migration and subsequent reaction of the liner aziridines in the propellant.

Chemical testing of propellant from Motor MSEX-2 after 24 mo aging was conducted on plugs from the forward chamber and mid-barrel region. Comparison of the amount of extractable CTPB after 24 mo aging to 12 mo aging at these two locations is shown in Figure 31. The aging trends are (1) no

VI.C. Special Topics (Cont)

change at the bondline interface, i.e., interface remains highly crosslinked, and (2) a decrease at 24 mo at distances greater than 0.1 in. from the bondline which indicates the postcure reaction is occurring. The apparent degradation (softening) at the bondline in the forward chamber noted at 18 mo aging is not supported by chemical test data from the forward plug after 24 mo aging.

In contrast to the plugs, the chemcial properties of the analog cartons from Batch M5024 after 12 and 24 mo aging show some postcure occurring throughout the gradient, including the interface (see Figure 32). The additional hardening may also reflect oxidative crosslinking as a result of oxygen diffusing through the insulation/liner into the propellant.

A comparison of the amount of extractable CTPB from cartons and motor plugs shows the differences between the forward end and mid-barrel are similar to the differences between the cartons from the three batches in the motor. The ranges observed reflect the batch-to-batch variability within a motor. A further comparison shows less extractable CTPB throughout the gradient in the cartons, indicating the propellant in the analog carton is more highly crosslinked than the propellant from the motor plugs. This motor/carton bias is perhaps due to differences in kinetic mean temperature during cure. The motor/carton bias is also seen in the mini-tensile test results.

<u>Plugs - Propellant-Liner-Insulation Bond</u> - Strength of the propellant-liner-insulation bond (ANB-3066/SD-851-2/V-45) for plugs from the forward and mid-barrel of Motor MSEX-2 was determined using both constant rate tensile and high rate shear tests. Tensile tests were conducted using mini-sized specimens to reduce effects of curvature in the samples.

VI.C. Special Topics (Cont)

Bond shear strengths, measured at operational conditions,* are slightly higher in the mid-barrel (249 psi) than in the forward area (210 psi). Values have not changed significantly with aging from 12 to 24 mo.

Bond tensile strength in the forward end decreased from 98 to 78 psi with aging from 18 to 24 mo, while that in the mid-barrel was unchanged. Testing conducted on dissected motors indicates bond strength in case-bonded areas is not typically affected by aging. Differences in values from 18 to 24 mo may reflect differences in strength due to sample location: For four samples removed from the motor during initial testing, bond strength varied from 76 to 109 psi.

Source	Sample Type	Age, mo	Bond Strength, psi* Mean	Bond Strength, psi* Range	No. of Specimens
Population	Excise	0	75.4	56 to 92	24
MSEX-2	Excise	2.5	84	81 to 98	2
	Excise	24	65	55 to 78	3
	Plugs	12	97	76 to 109	8
		18	109	88 to 124	4
		24	90	70 to 110	4

*Based on mini-sized specimen, 77°F, 1.0 min^{-1}

Bond tensile and bond shear strengths for an analog sample were slightly improved with aging to 24 mo.

Plugs - SD-851-2 Liner - Chemical testing of SD-851-2 liner consists of swelling ratio and gel-filler fraction measurements. The swelling ratio values obtained are highly variable resulting from pre-stressing which occurs during removal of the thin liners (<0.03 in.) from V-45 insulation.

*77°F, 200 in./min, 600 psig.

VI.C. Special Topics (Cont)

Various methods to reduce the effects of pre-stressing of liners from motors are being investigated. The pre-stressing of liners has little effect on gel-filler fraction, which measures the soluble species diffusing out of the polymer and is dependent on the thickness of the liner. Values reported are corrected for variations in liner thickness. A complete discussion of the correlation of liner thickness and gel-filler fraction is presented in Appendix A of SAAS 34. Test results are listed in Appendix C.

Chemical test results of the liner from the chamber area of Motor MSEX-2 show a wide range of properties between motor locations and between motor orientations such that no conclusions can be drawn on the effects of aging on the liner. The chemical test results are listed below:

Motor Location:		Forward Chamber		Mid-barrel		Aft Chamber	
Time, mo	Orientation, deg	Se/So	Gel	Se/So	Gel	Se/So	Gel
12	30	1.87	0.671	1.89	0.678	1.70	0.670
12	210			1.65	0.668		
18	75	1.70	0.666			1.84	0.699
24	120	1.72	0.633	1.69	0.658		

Unlike the chamber region, the liner from the aft boot shows aging trends similar to the trends of the analog carton liners. This similarity is expected as the analog cartons simulate the aft boot area of a motor. Test results follow:

	Analog Carton		Excised Sample	
Time, mo	Se/So	Gel	Se/So	Gel
2.5			1.88	0.703
12	1.80*	0.652*		
24	1.87	0.612	1.89	0.613

*Average of 3 cartons

VI.C. Special Topics (Cont)

Plugs - V-45 Insulation - Response properties of V-45 insulation from plugs were evaluated by stress relaxation tests conducted at 77°F with 2.0% applied strain. Relaxation modulus of material from the forward and mid-barrel increased as expected. Higher modulus in the forward location in comparison with the mid-barrel is due to increased thickness of the material in that location.

Property	Age, mo	Plug Location	
		Forward	Mid-barrel
E_{r_1}, psi*	12	1285	704
	18	1259	-
	24	1555	1160

*Relaxation modulus at one minute.

Relaxation modulus for insulation from an analog sample increased as expected with aging.

Chemical testing of V-45 insulation from plug motors consists of swelling ratio, gel-filler fraction, weight % moisture, and weight % DOP. Insulation in the forward and aft chamber areas is thicker than the insulation in the mid-barrel and boot areas. The thicker insulation is split in half before testing in order to distinguish between the condition of the insulation near the liner and near the case. Complete test results are presented in Appendix C.

Based on previous testing of V-45 insulation, the following conclusions have been made:

(1) Gel-filler fraction is affected by changes in DOP concentration, moisture content, and crosslink density

VI.C. Special Topics (Cont)

(2) The concentration of DOP depends on time, insualtion thickness, and whether the insulation is case-bonded or not (the presence of case restricts the direction of diffusion towards the liner)

(3) The moisture content depends on the amount of moisture present in the case bonded insulation at the time of motor lining. Additionally, the relative humidity in the motor will affect moisture content in the boot insulation

(4) V-45 insulation is anisotropic and thus the swelling ratio depends on the orientation of the test specimen. The difference in the swelling ratio values between the two perpendicular directions is approximately 0.04.

The chemical properties of the samples tested at 24 mo are shown below. The observed range in gel-filler fraction values reflects the net changes in the amounts of DOP and moisture in the insulation. The apparent higher crosslink density (lower swelling ratio) in the mid-barrel region is probably a result of different orientation of the samples compared to the forward and aft areas.

Chemical Test Results at 24 Months

Location	Se/So	Gel	% DOP	% Moisture
Forward	1.74	*0.846/0.832	*4.21/6.3	1.51
Mid-barrel	1.69	0.882	1.04	1.73
Excised		0.856	3.40	1.94
Analog	1.74	0.864	2.67	1.94

*Insulation near liner/near case

VI.C. Special Topics (Cont)

Ignition Delay - Test results from this motor show consistently lower performance for the three IDMs tested thus far. The IDM performance is not consistent with the observed finocyl surface or SEM data. Some offset is to be expected between motor excise samples and analog samples. No explanation exists for the relatively lower pressurization rates produced by this propellant. Too little data exists at present to determine any trends affecting ignitability.

	IF	Ignition Delay Prediction
Motor Excise Samples:	1289	0.134 sec
Analog Carton Samples:	1447	0.113 sec (PQA x = 0.103 sec)
	vs	
Zero Time Excise Samples:	1634	0.112 sec

Motor AA21480 (1976 Vintage)

Background - Motor AA21480 was cast May 1976 from Lot Combination 67, propellant Batches 4939, 3940, and 4941, formulated with Phillips CTPB. The motor was assembled into Missile M67-551 in September 1976. It was installed in Silo 2B11 in October 1976 where it remained until December 1984. It was received at ASPC in March 1985 for plug motor testing.

Evaluation of Initial Properties - Round-gallon samples containing propellant cast into full-scale motors are routinely tested to evaluate mechanical properties of each motor. As a result, uniaxial tensile properties are available for propellant batches cast into Motor AA21480. Data indicate propellant cast into Motor AA21480 is typical of production material.

VI.C. Special Topics (Cont)

Qualification Data at 77°F, 0.74 min^{-1}

Lot Combo	Batch No.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	Shore A
67	4939	94.2	34.8	53.7	468	51
	4940	99.0	33.9	47.9	488	50
	4941	98.3	35.4	51.6	473	50
		Target			450	
		Range			300 to 600	

Excise Sample - A sample was removed from the aft end of Motor AA21480 for comparison with aging trends established from a population of 113 full-scale motors. Test results, included with comparable data for the population (Section VI.A.), indicate material from Motor AA21480 is typical of aged Phillips propellant:

- Hard bore surface to approximately 1.0 in. (higher modulus, lower strain capability than at >2.0 in. from surface), Figure 3
- Hard propellant at the bondline to approximately 1.0 in. from the interface, Figure 4
- Reduced bond tensile strength in the aft end, Figure 7.

Values for bond and propellant properties for Motor AA21480 are above average in all cases, but within the range of previously tested motors of comparable age.

Bore Sample - A 5 x 4 x 2.5-in. propellant sample was removed from the aft bore region of Motor AA21480 to assess effects of aging in the critical bore location. Data are compared with results from a population of 5 samples removed from motors formulated with Phillips CTPB. Uniaxial tensile properties, measured at 77°F, 0.74 min^{-1}, are within the range of values for motors aged 171 to 181 mo. At high rate conditions with

VI.C. Special Topics (Cont)

superimposed pressure, strength and modulus are lower and strain is slightly higher than values for the older motors. It is expected that with additional aging, propellant from Motor AA21480 will continue to harden.

Test	Temp, °F	Strain Rate	Property	Motor AA21480 L.C. 67 110 mo	Range of 5 Motors L.C. 3, 14, 15, 16 171-181 mo
Uniaxial Tensile	77	0.74	σ_m, psi	161-168	127-210
			ϵ_m, %	12-15	8-20
			ϵ_b, %	16-19	8-34
			E_o, psi	1642-1859	1044-2912
with 600 psig	77	74	σ_m, psi	452-498	516-576
			ϵ_m, %	23-27	15-24
			ϵ_b, %	25-27	15-27
			E_o, psi	2708-3390	3738-5547
Stress Relaxation ϵ = 2.0%	77	0.25	E_{r1}, psi	1052	760-1395

Strain capability in the bore is greater than that in the aft end for Motor AA21480. Tests conducted on 25 samples showed strain capability usually lower in the bore (SAAS-34).

<u>Plugs - Propellant</u> - Uniaxial tensile testing of plugs removed from the forward, mid-barrel (2 locations), and aft end of Motor AA21480 indicate significant difference in properties among four plug locations. Propellant from the mid-barrel exhibits higher modulus and strength than that removed from the forward or aft ends. Strain capability is comparable among test locations.

VI.C. Special Topics (Cont)

Type Specimen	Location	Uniaxial Properties at 77°F, 0.74 min^{-1}				
		σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	Shore A
JANNAF	Forward	143	16	22	1385	64
	Mid-barrel	154	15	21	1582	64
	Mid-barrel	152	14	19	1648	58
	Aft	144	15	20	1471	60

Propellant properties in the mid-barrel approach values noted for propellant from the bore sample.

Gradients from the bondline were measured at 77°F, 1.0 min^{-1} using mini-sized specimens. Results indicate expected hardening adjacent to the bondline (0.1 in.) (Figure 33). Data support results using standard-sized specimens in indicating harder propellant in the mid-barrel.

Chemical testing of propellant from Motor AA21480 (aged 110 mo) was conducted on four plugs from the chamber (forward, mid-barrel(2), aft) and a sample excised from the aft boot. No significant difference is seen in the amount of extractable CTPB in the gradients from the bondline interface between the forward, mid-barrel, and aft sections of the motor (see Figure 34). Each section follows the expected gradient trend; the bondline interface is more crosslinked (harder) compared to propellant farther than 0.1 in. from the interface.

Significant differences are seen in the amount of extractable CTPB between the excised sample from the aft boot and the chamber sections of the motor. In the excised sample, the propellant is less crosslinked at the bondline interface than the chamber sections. The softer interface in the excised sample may be a result of hydrolytic degradation of TMAT. The amount of extractable CTPB in the gradient 0.2 in. to 1.0 in. from the bondline is similar among all samples tested. However, the propellant 2.0 in. from the

VI.C. Special Topics (Cont)

bondline shows considerably more CTPB is extracted from the excised sample compared to the other sections. The soft bulk propellant in the aft boot excised sample is also observed in mechanical properties. The soft bulk propellant is attributable to flow characteristics of the propellant.

Plugs - Propellant-Liner-Insulation Bond - Bond strength for plugs from Motor AA21480 was measured using constant rate tensile and high rate shear tests. Results are tabulated in Figure 35. Bond tensile and shear strengths are higher in areas of increased propellant strength (mid-barrel locations). Bond tensile strength in case-bonded areas (plugs) is significantly higher than that in the aft boot (average of 107 psi for 4 plugs vs 44 psi in the aft end).

Plugs - SD-851-2 Liner - Chemical test results of the liner from the chamber area of Motor AA21480 show lower gel-filler fraction values for the liner from the forward and aft areas compared to the mid-barrel. The lower gel-filler fraction values may be the result of two possible mechanisms related to insulation thickness, (1) more hydrolytic degradation of the liner in the forward and aft areas due to a greater amount of moisture in the thicker insulation, and (2) higher DOP concentration in the liners next to thicker insulation in the forward and aft areas.

No conclusions concerning differences in crosslink density due to hydrolytic degradation can be made because the swelling ratios obtained are affected by pre-stressing of the liner during removal from the insulation. Relative concentrations of DOP in the liner are measured by FTIR analysis of chloroform extracts of the liner. Comparison of the heights of the peak characteristic of DOP at 1,295 WN (normalized to the initial weights) indicates more DOP is present in the liner from the forward chamber than in the liner from the mid-barrel. FTIR analysis of liner extracts from the plug motors is recommended to verify the differences in the concentrations of DOP. The chemical test results are listed below:

VI.C. Special Topics (Cont)

Motor Location		Forward Chamber		Mid-barrel		Aft Chamber	
Time, mo	Orientation, deg	Se/So	Gel	Se/So	Gel	Se/So	Gel
110	30	1.76	0.637	1.68	0.678	1.68	0.645
110	210			1.83	0.680		

The test results from the sample excised from the aft boot (Se/So 1.89, Gel 0.454) are discussed in Section VI.A. with the motor excised samples.

Plugs - V-45 Insulation - Relaxation modulus of V-45 insulation from the plug locations was measured at 77°F, with 2.0% applied strain. Values for E_{r1} range from 1,191 psi in the forward chamber to 1,648 psi in the mid-barrel. For insulation from the aft end (exposed to environment), relaxation modulus at one minute is 2,592 psi.

The chemical properties of the samples tested at 110 mo are shown below. The observed range in gel-filler fraction values reflects net changes in the amounts of DOP and moisture in the insulation. The close agreement of swelling ratios between the various locations in the motor indicates the insulation samples were tested in the same direction.

Chemical Test Results at 110 Months

Location	Se/So	Gel	% DOP	% Moisture
Mid-barrel (30°)	1.68	0.899	0.48	1.79
Mid-barrel (210°)	1.67	0.898	0.51	1.95
Forward (30°)	1.66	*0.863/0.848	*3.31/5.94	1.59
Aft (30°)	1.66	*0.861/0.846	*3.26/4.67	1.75
Excised Aft Boot	1.64	0.890	1.67	1.77

*Insulation near liner/near case.

VI.C. Special Topics (Cont)

2. Early Age-Out of Stage II Motors

a. Introduction

Eleven of 56 motors visually inspected at 00-ALC during routine operations have been scheduled for early remanufacture due to premature liner degradation in the boot nipple area. The rejected motors ranged in age fro 10 to 14 years at time of inspection. The basis for rejection by 00-ALC is presence of a forward boot gap of greater than 1/32 in. around the circumference of the boot. A summary of rejected motors is provided in Figure 36.

As a result of the discovery by 00-ALC of prematurely aged motors, an investigation is underway to investigate potential causes of the condition and evaluate impact on other operational motors.

b. Approach

The program incorporates testing of affected motors (to measure extent of degradation) with a comprehensive evaluation of available historical databases (to identify variables which may affect aging behavior). Data are available from several sources:

	Source	Information Available	Motor Vintage
1.	ASPC Manufacture Processing Data	Raw materials acceptance testing, insulation preparation, liner, and propellant mix, cast, and cure	Limited to 5/72 to 3/77 for this study
2.	ASPC Visual Inspections	Propellant appearance, boot gap, and lifting liner condition for 238 14 to 19 yr old motors	5/65 to 1/72
3.	00-ALC Storage Histories	Silo locations and conditions for each motor in the field	As available

VI.C. Special Topics (Cont)

	Source	Information Available	Motor Vintage
4.	ASPC Motor/Carton Aging Data	Propellant and bond properties for approximately 113 excise samples; dissected Stage II, III motors	2/65 to 10/72 7/64 to 3/71
5.	OO-ALC Carton Data	Bond properties for materials cast into 36 motors	4/72 to 1/79

Properties of the affected motors will be compared with aging trends established for the Stage II motor, Item 4. Information from manufacturing process data, visual inspections, and storage histories, Items 1, 2, and 3 will be used to update the manufacturing variables study performed during the LRSLA program. This study will identify variables which could potentially affect aging behavior (Reference 6). Carton data from Air Force testing, Item 5, is of particular value because cartons represent motors of the same vintage as the affected motors. Anomalous carton data will flag suspicious motors or liner lots for further inspection. A logic diagram for the program is provided in Figure 37.

c. Status

Testing is complete for propellant-liner-insulation samples removed from 4 affected motors (Motors AA21049*, AA21051, AA21321*, and AA21434). Testing of Motor AA21067 is in process. Results for Motors AA21051 and AA21434 are reported in Section VI.A. in comparison with the population of excised motors.

Statistical analysis of visual inspection histories is complete for input into the manufacturing variables study.

*Results are reported in SAAS-35

VI.C. Special Topics (Cont)

A computerized database for motor manufacturing histories is in process. Included are processing data for 400 motors manufactured between 1972 and 1977. Data entry should be complete by mid-April.

Carton aging data available from Hill AFB are being incorporated into the database. Constant load and constant rate bond data have been received from Hill AFB. Additional bond and liner data, not yet received, should also be included for this study.

Analysis of the aging and manufacturing data will be conducted from April through July. A final report will be provided at the completion of this task.

VII. TECHNICAL DISCUSSION OF COMPONENTS

A. IGNITER FIRINGS

1. VECP Igniters (TP-14B)

Nineteen igniters were fired in August and September 1985 for VECP B-177. Igniter ages ranged from 190 to 259 mo (15.8 to 20 yr) and test results are shown in Figure 38. All parameters of all igniters fired were within specification limits except for four igniters (stored unsealed) which had igniter delays above the specification limit. None of the parameters indicate an aging trend which would limit service life to less than 34 years.

Seven igniters had delays outside both individual Lot Acceptance and overall Lot Acceptance 3σ limits (Figure 39). These high delays were thought to be a result of either the type of squibs or firing fixture used for testing, or igniter moisture contamination due to unsealed storage. VECP B-177 was extended to fire six additional igniters to isolate the cause

VII.A. Igniter Firings (Cont)

of the igniter delay anomaly (Reference SAAS 35). This increased the total number of igniters fired for VECP B-177 from 19 to 25.

Results of the six additional firings show that igniters which were stored unsealed are prone to high igniter delay and high delay variability. Storing igniters unsealed may permit igniter propellant grain and initiator pellets to absorb ambient air moisture. High delays and delay variability is more pronounced in post Lot 31 igniters, possibly because these igniters contained less initiator charge. Test configuration was discounted as a contributor to high igniter delay or delay variability. Six igniters fired for FY 1985 and FY 1986 aging and surveillance were all sealed and data support the conclusion that unsealed igniters have higher delays and greater delay variability than sealed igniters. The unsealed igniters were from the population stored prior to the inception of the VECP.

Analysis includes data from OP, PQA, VECP B-177, and aging and surveillance igniter firings. LAT data was not used because it was a different population and the quantity would "anchor" regression lines at zero time. Analysis results summary is shown in Figure 40. Listing of data used for analysis is presented in Appendix D.

Least-squares linear regression was conducted on a pooled population of all lots. Plots of igniter delay, burn duration, average pressure, maximum pressure, and pressure-time integral are shown in Figures 41 through 45, respectively. The Student-t-test was applied to regression results to test regression significance at 95% confidence level. The regression is significant for burn duration, maximum pressure, and pressure-time integral, but the slopes are small enough to allow a large margin from the specification limit at 34 years of age. Igniter delay and average pressure have regression slopes that are not significantly different from zero. The population was broken into a group of igniters aged 2 to 100 mo and a group aged

VII.A. Igniter Firings (Cont)

101 to 239 mo, where 239 mo is the age of the oldest igniter fired to date. Variance analysis was done to detect if the variance increased between these two aging groups. An increase of variance, indicated by F-value, would be a possible indication of aging. For all parameters variance difference between these two age groups is small, and means are approximately equal, thus, aging effects are negligible. Results are summarized in Figure 46.

Analysis results indicate that the ballistic parameters of Minuteman Stage II igniters have changed very little, if any, in the past twenty years and that no aging trend currently exists which would limit igniter service life to less than 34 years. Testing has shown that igniters stored unsealed have high igniter delay variability and can have delays above specification limits. As long as igniters are continuously stored sealed, igniter delay remains fairly constant with age.

2. <u>Aging and Surveillance Igniter Firings (TP-14B)</u>

Two igniters were fired for FY 1985 and four were fired for FY 1986. Results and analysis of these firings are included in Section VII.A.1.

B. TVC AND RC GAS GENERATORS (TP-11A)

Four TVC and two RC gas generators are scheduled for firing in FY 1986 for VECP B-176 and the aging program. Results and analysis of these generator firings will be reported in SAAS-37.

C. LITVC BLADDER PERMEATION (TP A-59)

Bladder permeation testing of toroidal tank assemblies T-159 and T-210 began in April 1985. Both tanks contain Uniroyal bladders with DIAK-2

VII.C. LITVC Bladder Permeation (TP A-59) (Cont)

curative. Freon permeation continues to be similar to previous test results. A plot of permeated Freon vs time is shown in Figure 47. Permeation rate continues to be low enough to ensure adequate Freon available for expulsion after 17 years of motor storage.

Leak testing of contingent tanks T-200, T-213, and T-215 was done on October 25, 1985. All three tanks had Freon leakage at the tank/insert gasket and the Freon fill port. Tank weighing continues to show that the rate of Freon loss is low enough for leakage to be considered harmless to system performance. Figure 48 shows tank weight versus age for all three tanks.

D. TVC TANK AND COMPONENTS (TP A-59)

1. Cold Gas Expulsion Testing (TP-A59)

The results of 1986 cold flow gas expulsion testing has shown that aging of TVC tank burst diaphragms in a Freon environment for up to 238 mo does not change diaphragm burst pressure. TVC tanks ABB 1510 and ABB 0800 were tested January 31 and February 4, 1986, respectively. Tank ABB 1510 was 224 mo old and Tank ABB 0800 was 238 mo old at test. Both tanks contained Arrowhead bladders. Data used for analysis are presented in Appendix D.

The pressure/time curves recorded for both systems show significant noise but not enough to make pressures at burst rupture undiscernible, (Figure 49).

A linear regression of data shows a slight upward trend of burst pressure, but analysis shows the trend is not statistically significant (95% confidence), Figure 50.

VII.D. TVC Tank and Components (TP A-59) (Cont)

Variance analysis was done by comparing burst pressures of burst discs aged 100 mo or less with burst discs aged greater than 100 mo. Analysis shows that the means and the variance of these two populations are not significantly different.

Testing and data analysis done in FY 1986 supports the conclusions that there is no aging trend which would limit TVC burst diaphragm service life to less than 17 years.

2. Aging of Uniroyal Viton Rubber (MRP-049)

MRP-049 is the plan designated for the requalification of Uniroyal as the vendor and DIAK-2 as a curative ' - the bladder-collector subassembly for the Minuteman Stage II TVC system. As part of the qualification plan, a study was made to evaluate the mechanical behavior of the Viton rubber manufactured by Arrowhead and Uniroyal. The results of that study were reported in SAAS-33, Appendix D. In addition to the comparison study, a three year storage of the Uniroyal rubber in Freon was initiated. The results for the first two years are discussed below.

Storage temperatures for the specimens are 120 and 80°F with the specimens immersed in Freon or a Freon atmosphere. At the 6-mo aging increment the 120°F oven had a temperature excursion to 300°F for about 6 hours. This caused some of the glass sample container to overpressurize and burst resulting in some sample loss. The use of spare samples and the adjusting of the testing schedule will not compromise the aging study.

The test results to data show no difference between storage temperature, Freon vendor, and liquid or vapor atmosphere (Figure D-1, Appendix D). Therefore, the test analysis for this aging period treats the storage temperature or atmospheric conditions as one population. A summary of the data is presented below.

VII.D. TVC Tank and Components (TP A-59) (Cont)

Tensile test results on the Viton/Dacron composite for 24 mo aging show no significant trends and are comparable to results reported in SAAS-32 on the original Material Compatibility program, Figure 51. The elongation at break is somewhat greater than the original program and shows a trend to greater elongation with age, Figure 52. The change in elongation is probably due to the Freon softening the rubber allowing the fabric to better distribute the load among the fibers. Increased elongation of the composite is not expected to affect the functioning of the bladder.

The tear properties of the rubber and rubber cloth composite are a new aging test and cannot be compared to the original material compatibility programs. The rubber tear strength is degraded by the Freon soak but is expected to level off to a tear strength near 20 lb/T, Figure 53. The aging of the composite material indicates an initial dip in tear strength with a recovery to near the original properties, Figure 54. Tear strength of bladder EA0-0024, manufactured by Uniroyal returned from the fleet after 213 mo was measured at 170 T/lb for the composite and 32 T/lb for the rubber. Actual bladder tear values compare well with the aging data.

3. Requalification of Arrowhead AP-2707-3 Viton (MRP-075A)

Testing was performed on Arrowhead AP-2707-3 (DIAK 2 curative) Viton rubber to qualify the vendor as a second source for LITVC bladder collection assemblies. Results of tests completed on Arrowhead AP-2707-3 Viton rubber and composite are listed in Appendix E. The new Arrowhead AP-2707-3 rubber was shown to have elongation and tear strength greater than or equal to presently qualified Uniroyal 3094 and greater than previously qualified Arrowhead AP-2707-5 which was susceptible to cracking.

REFERENCES

1. Report ATF-II-SLA-1, Minuteman Second Stage Remanufacture Program, Service Life Analysis Program Plan, December 1984.
2. Interim Engineering Report, Aging and Surveillance Program III Stage II Program Progress Report 0162-06-SAAS-24, April 1980. Appendix A - Surface Hardening Kinetics, 30 May 1980. Appendix B - Ignition Delay Investigation of Minuteman ANB-3066 Propellant, Contract F42600-80-D-4416, 30 May 1980.
3. Minuteman Stage II Service Life Analysis, Appendix B - Ignition Delay Investigation, Contract F42600-81-C-4713, 1 July 1981.
4. Test Report MM-II-TP-9A, Determination of Propellant Moisture Level in Sealed Motors and Resulting Surface Hardening, Contract F42600-81-5211, March 1985.
5. Final Report, Investigation of Propellant Crack in Motor AA20629, Report MM-II-TP-018, November 1985.
6. K.W. Bills, Jr. and L.P. Trimberger "Manufacturing Variables Study of the Minuteman Stage II Motor - Action Item 269," 23 April 1976.

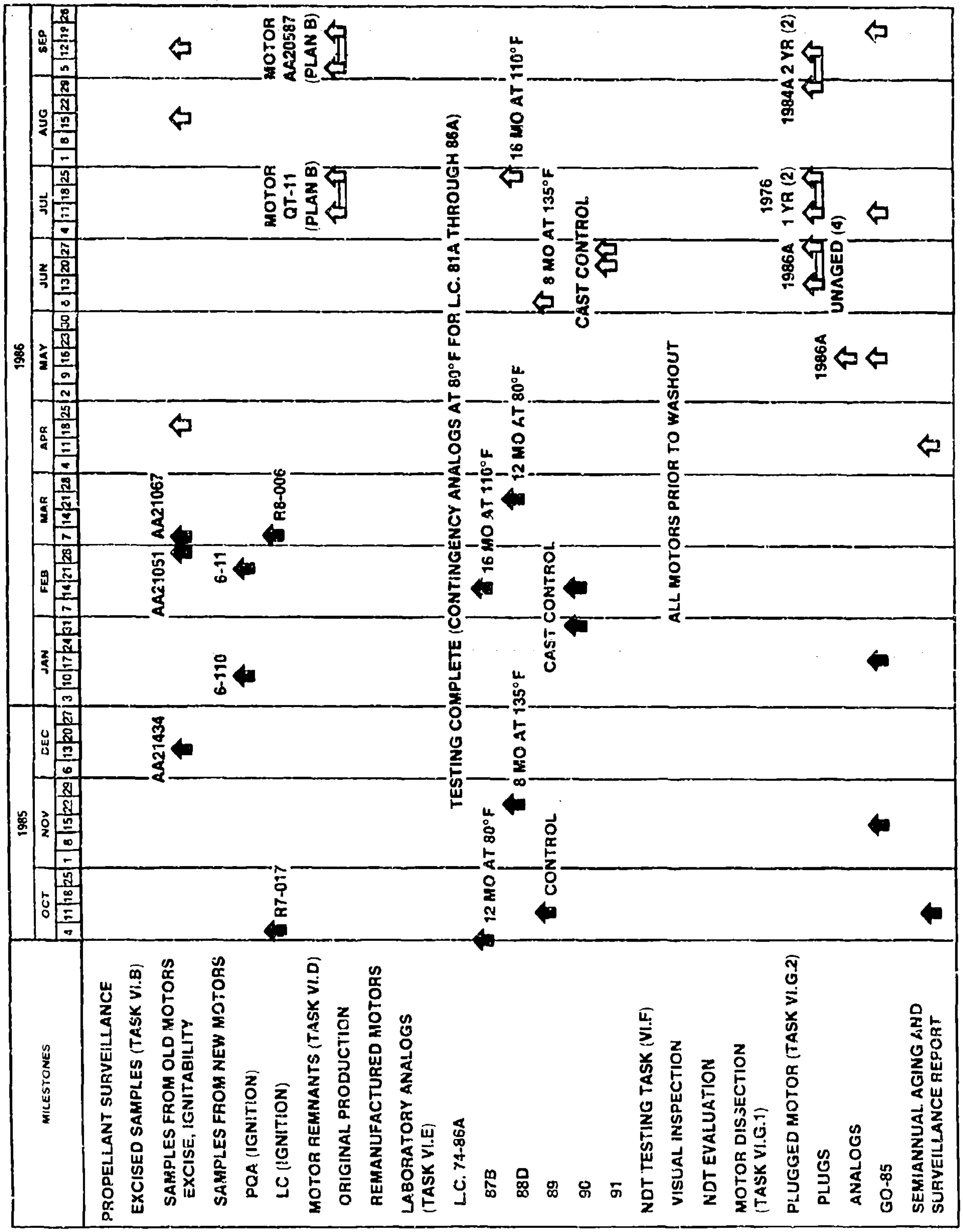


Figure 1. Milestone Schedule

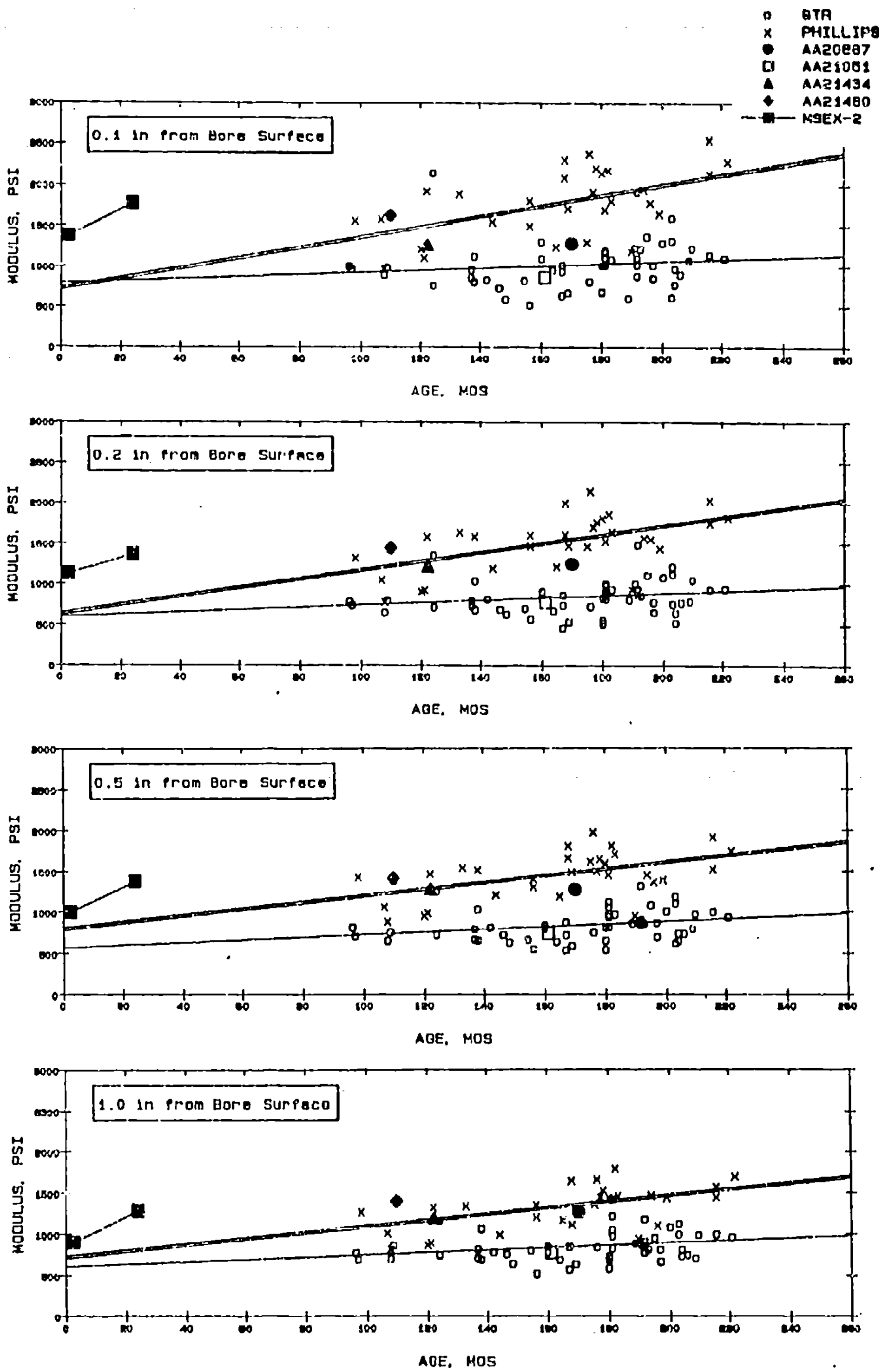


Figure 2. Effect of Age and Distance from Bore Surface on Initial Tangent Modulus ANB-3066 Propellant from Full-Scale Motors

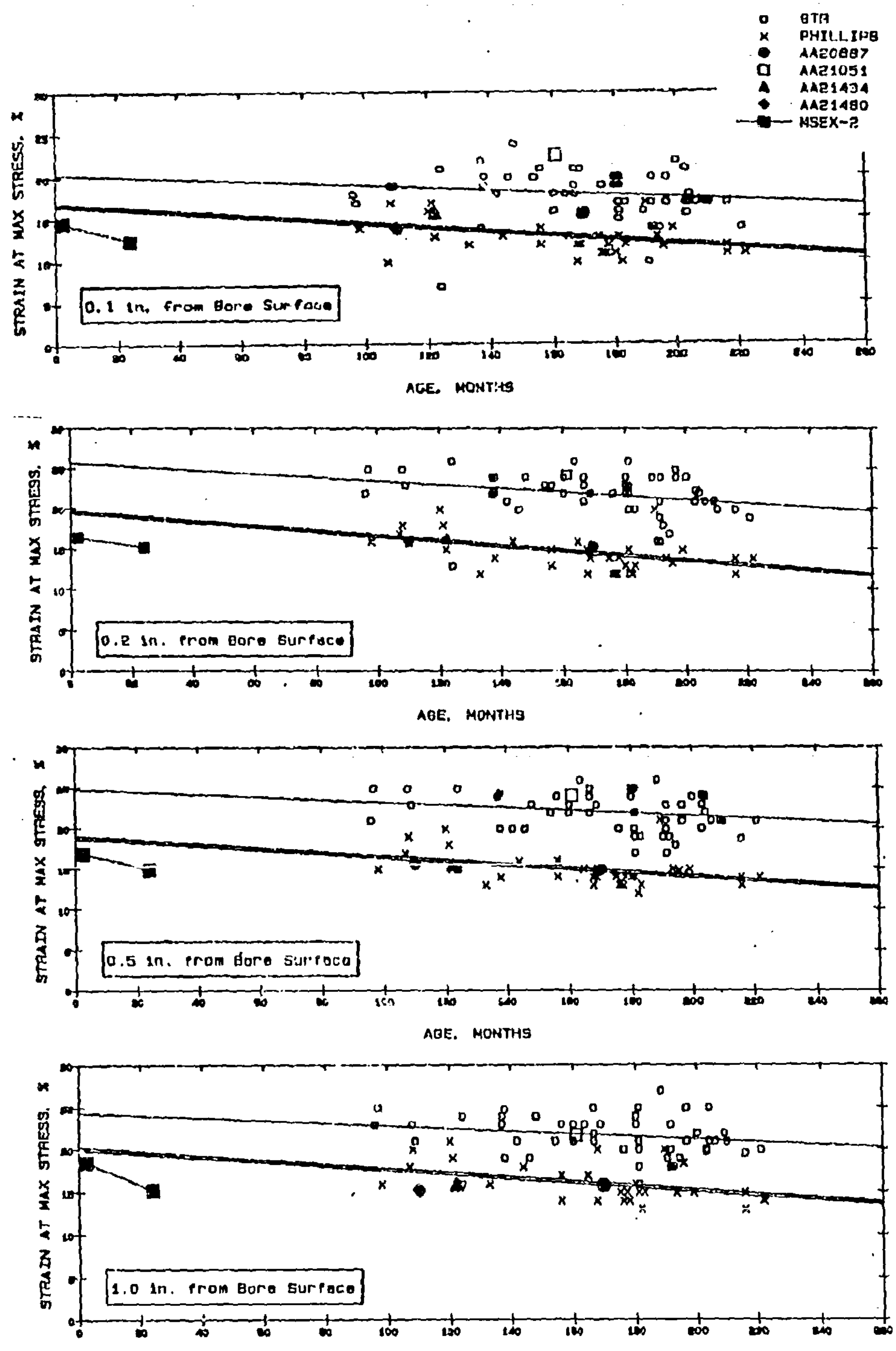


Figure 3. Effect of Age and Distance from Bore Surface on Strain Capability for ANB-3066 Propellant from Full-Scale Motors

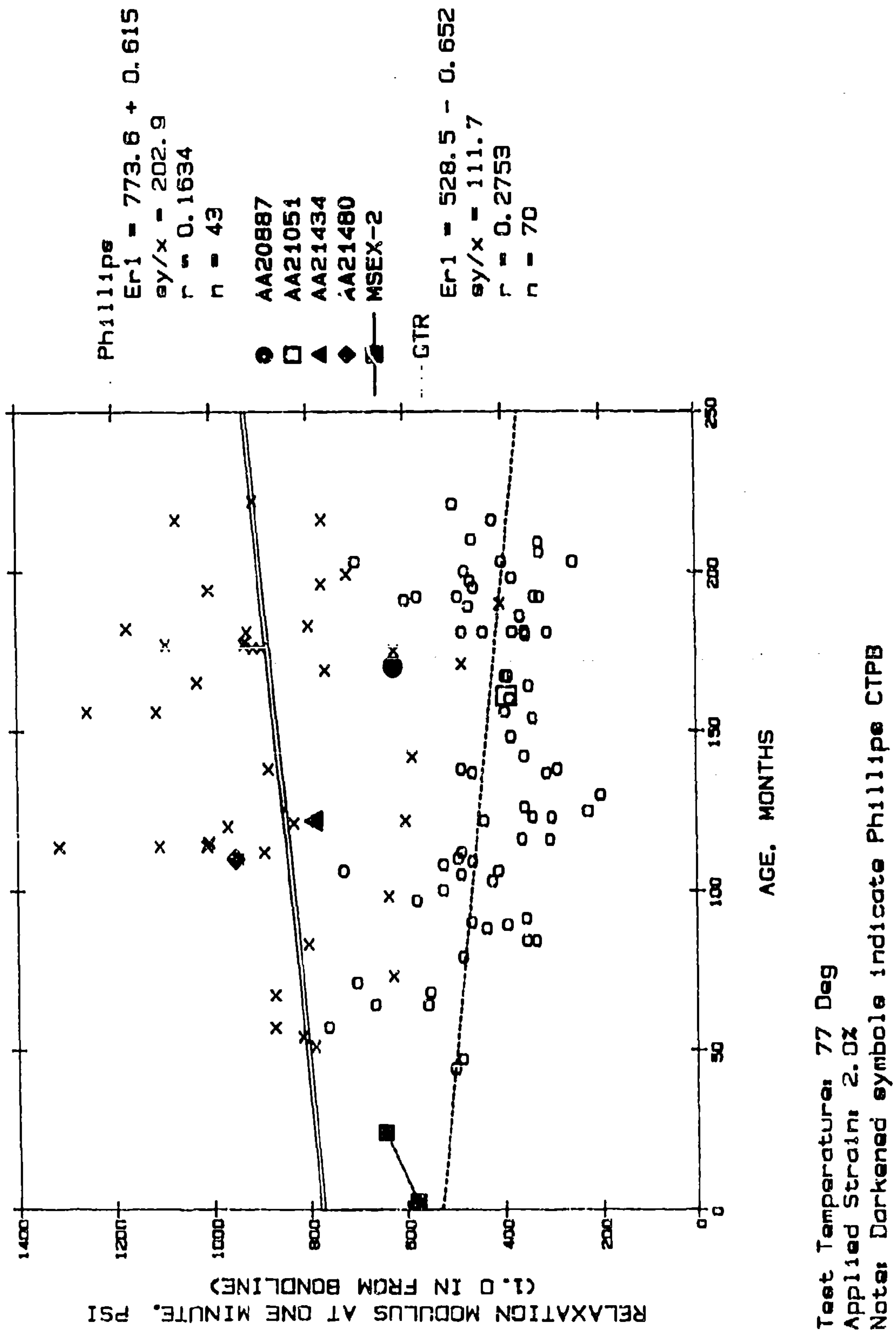


Figure 4. Effect of Aging on Relaxation Modulus of ANB-3066 Propellant Excised from Full-Scale Motors

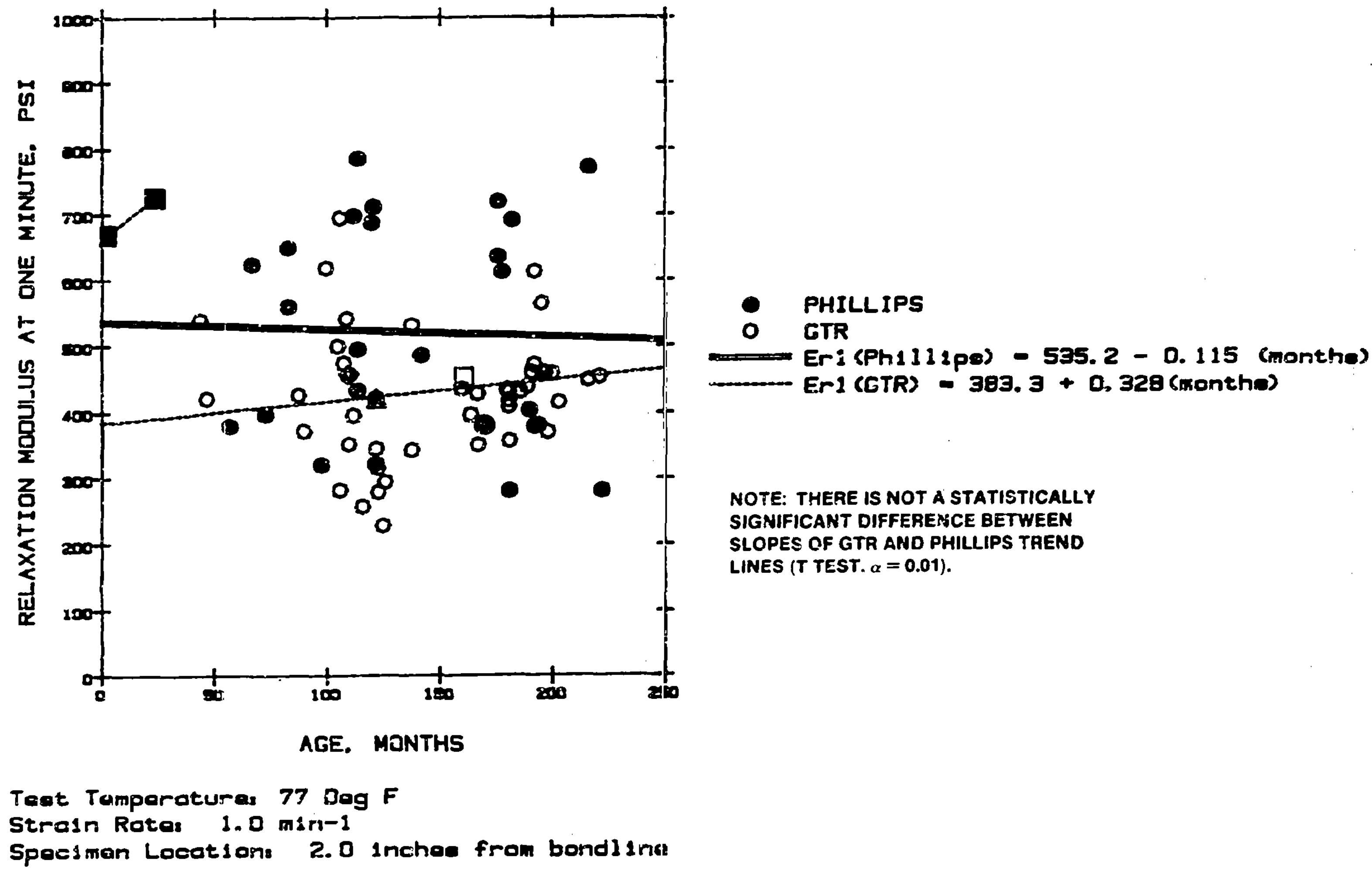


Figure 5. Effect of Age and CTPB Vendor on Relaxation Modulus of ANB-3066 Propellant from Full-Scale Motors (2.0-in. from Bondline)

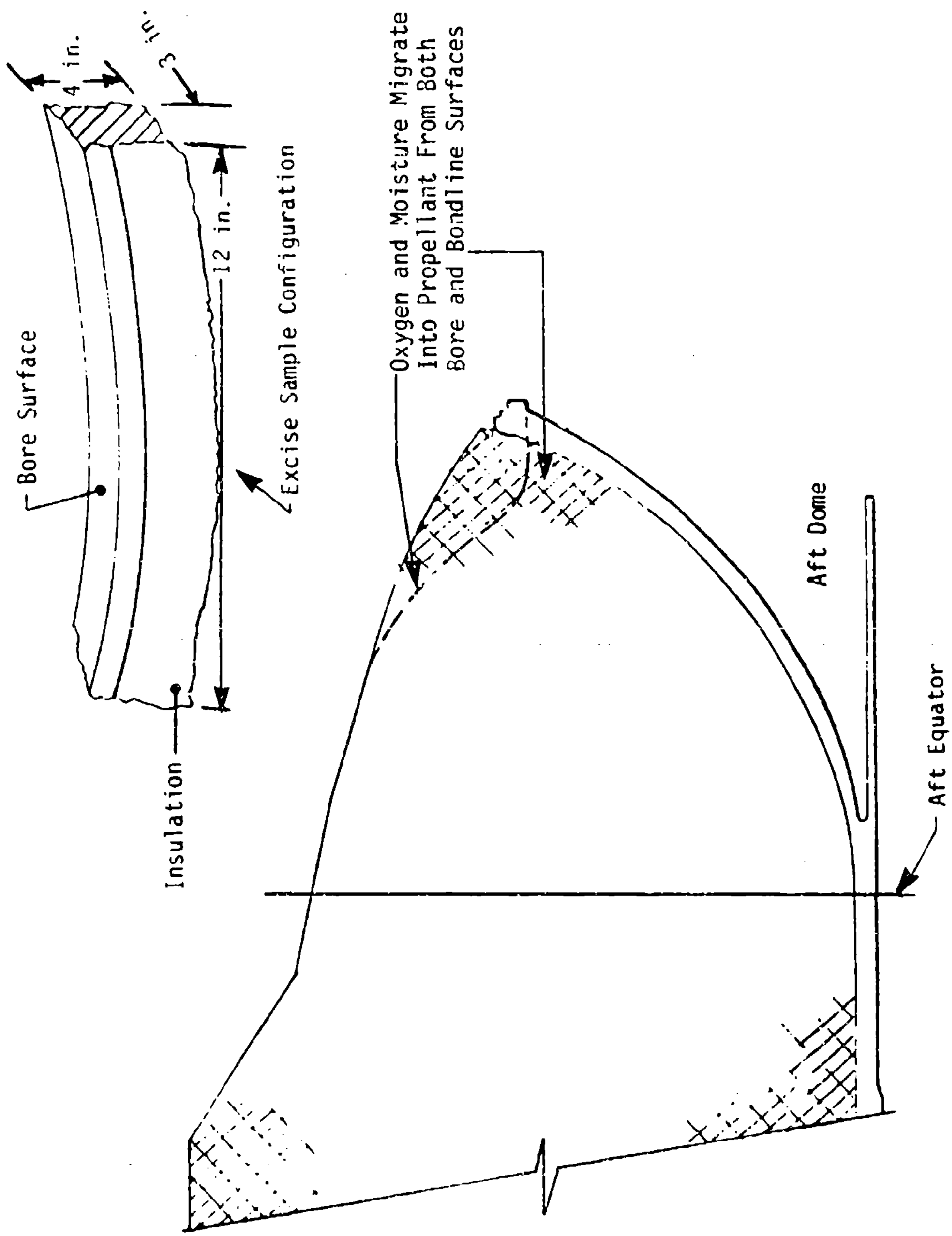


Figure 6. Typical Location of Aft Excised Propellant-Liner-Insulation Samples

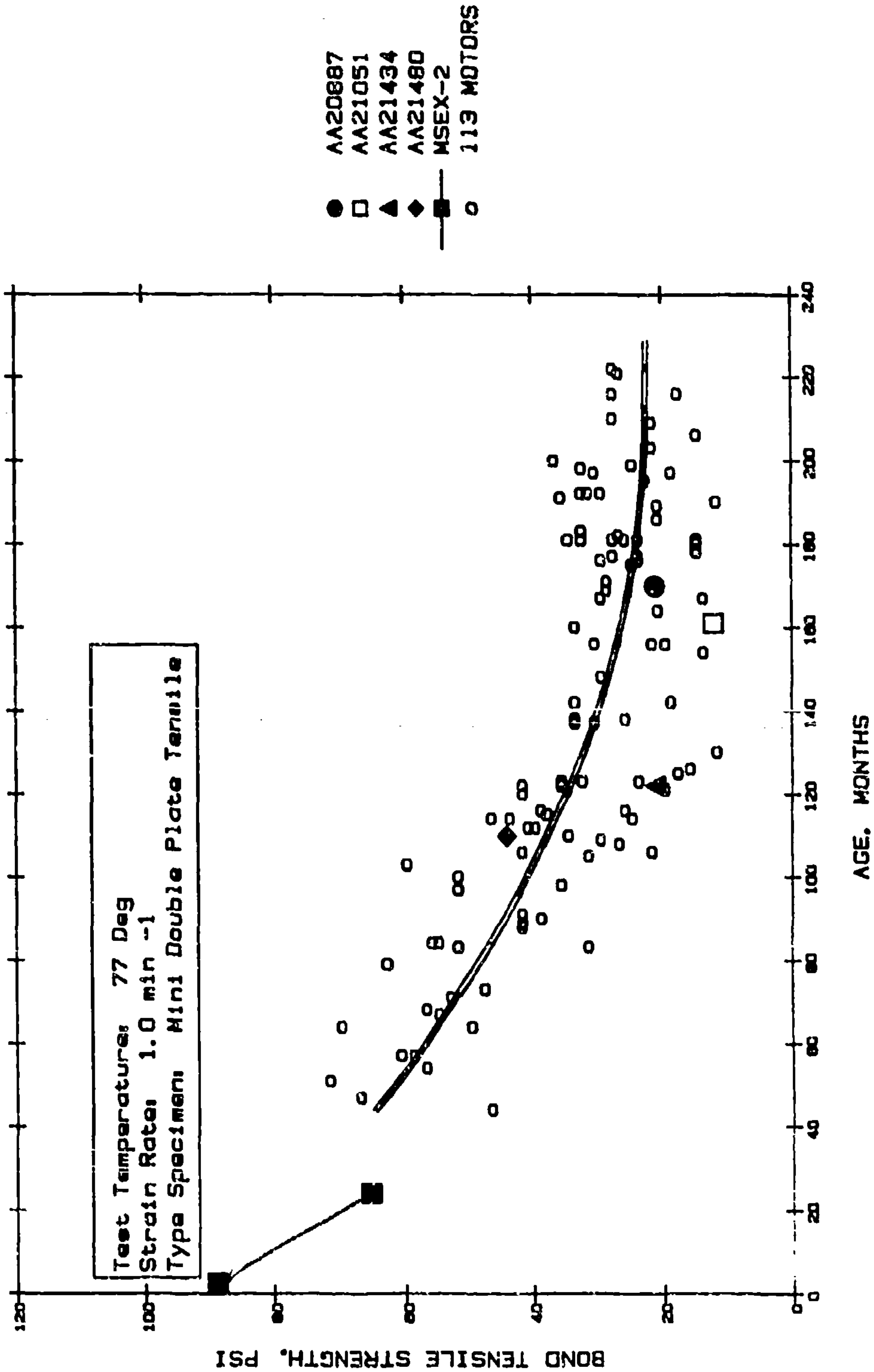


Figure 7. Effect of Aging on Bond Tensile Strength for Samples Excised from Full-Scale Motors

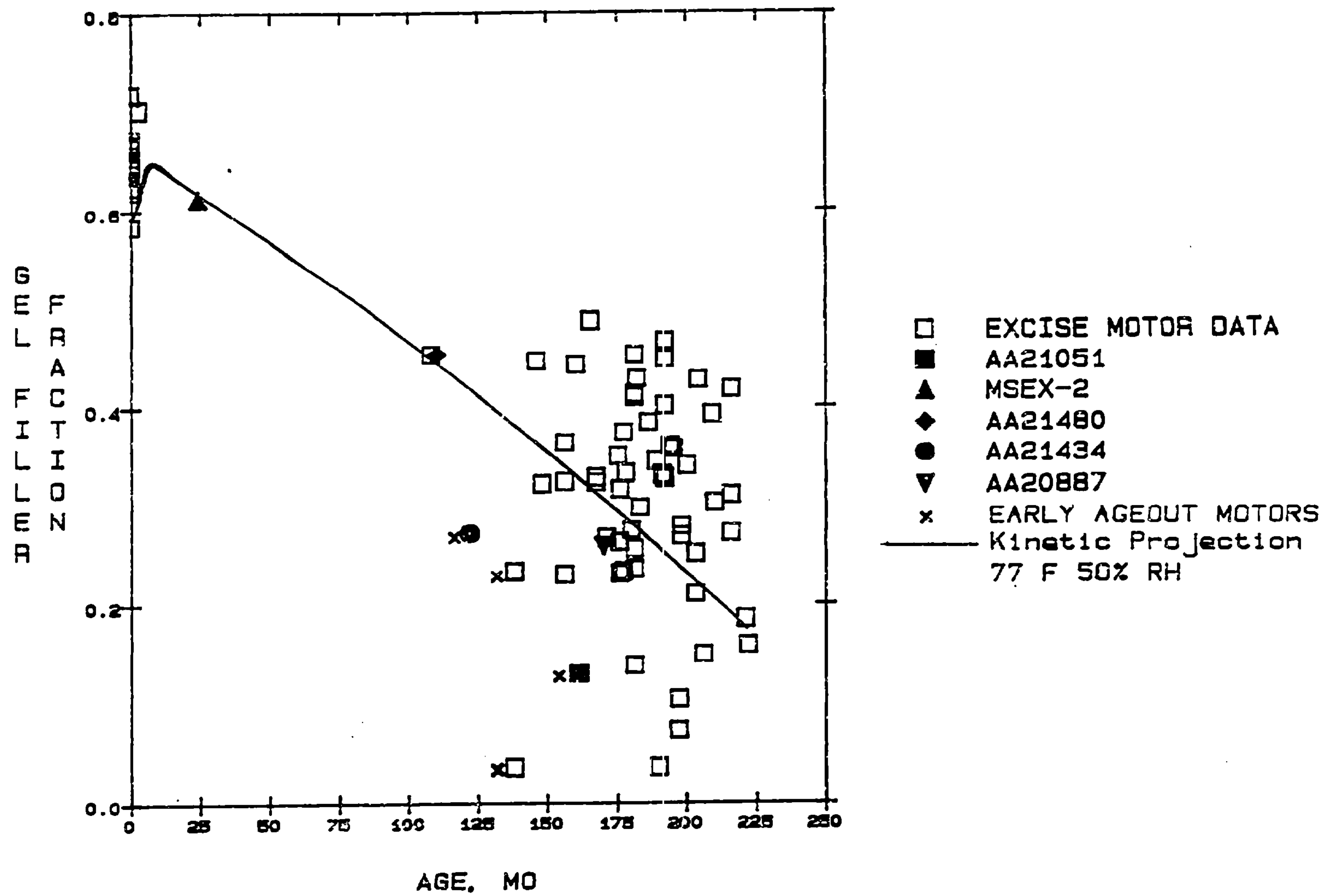


Figure 8. Gel Filler Fraction of SD-851-2 Liner from Motor Excised Samples as a Function of Motor Age

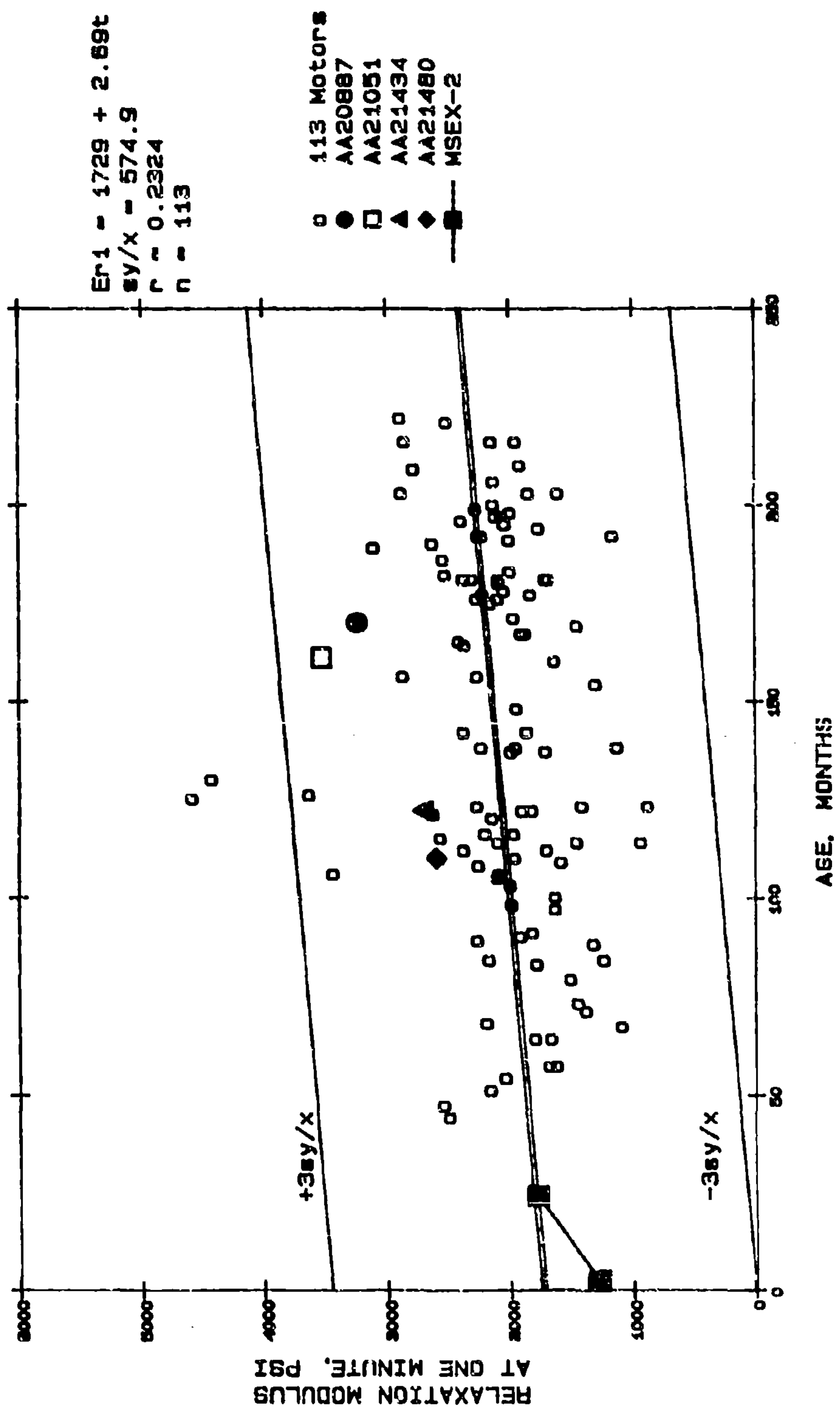


Figure 9. Effect of Aging on Relaxation Modulus of V-45 Insulation Excised from Full-Scale Motors

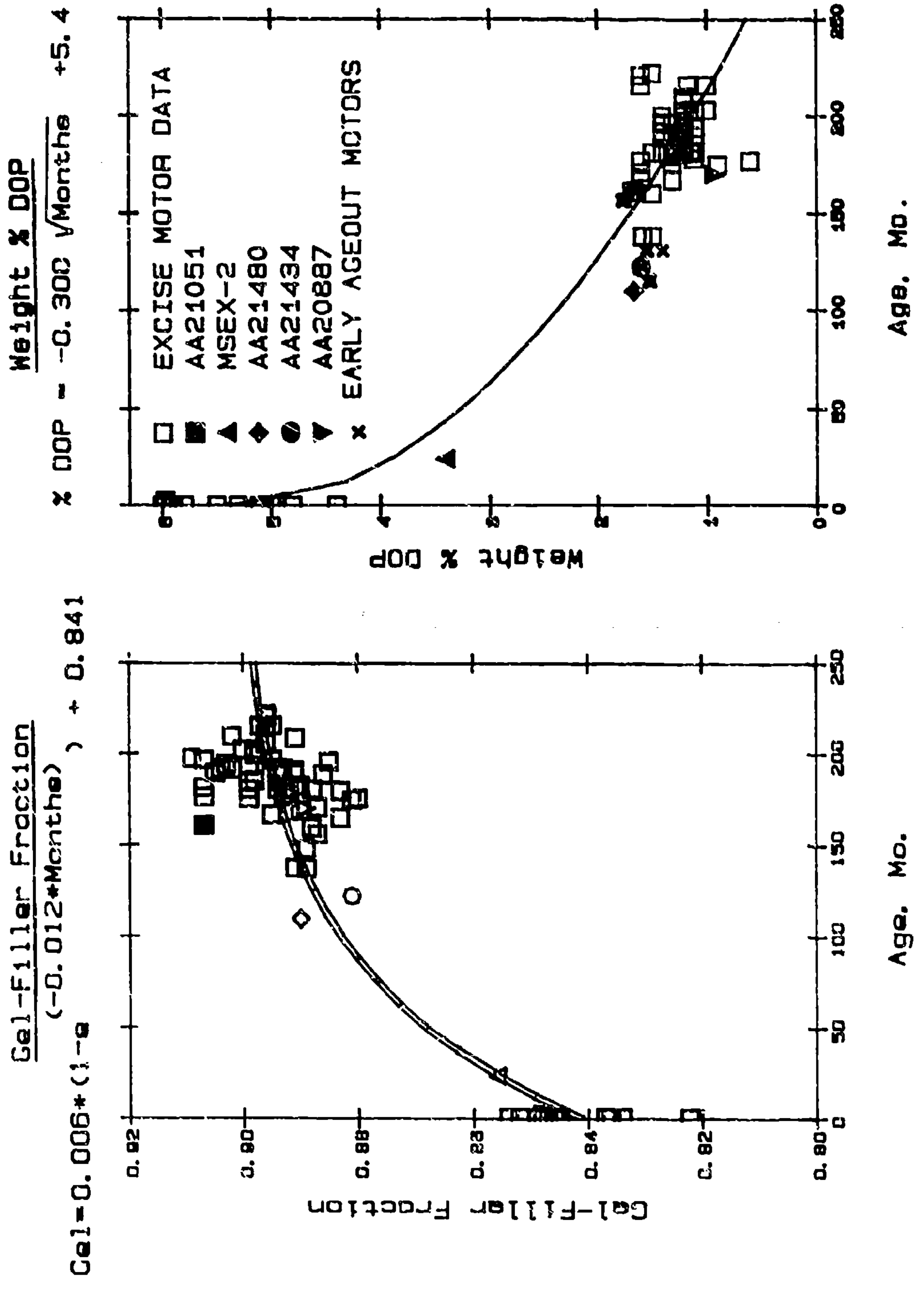
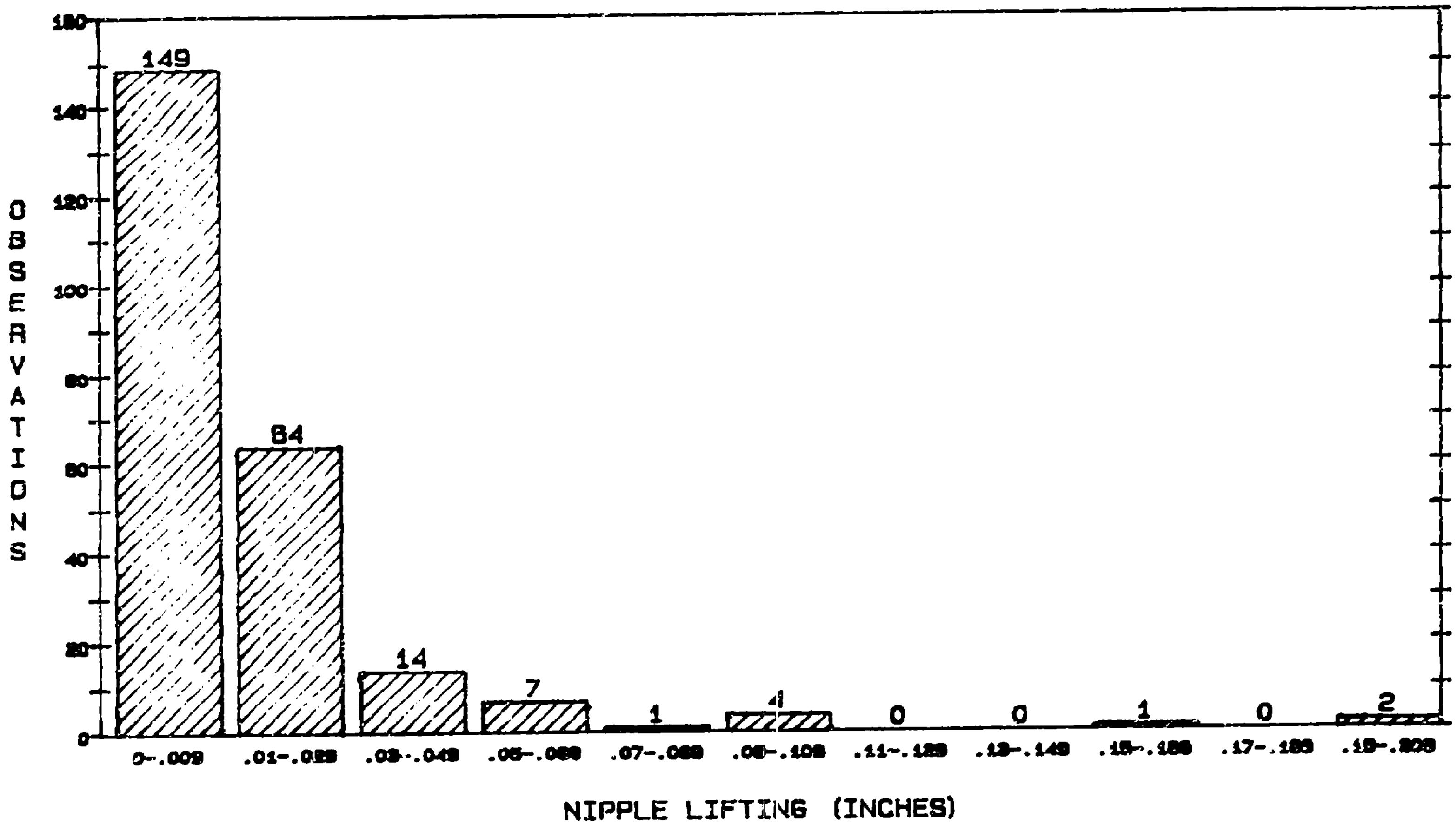
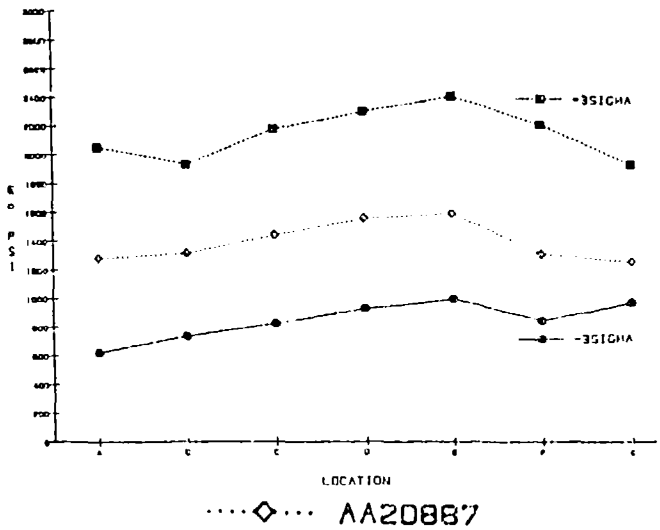


Figure 10. Chemical Properties of V-45 Insulation from Motor Excise Samples as Function of Motor Age



X = .011 INCH
UPPER 3 SIGMA LIMIT = .090 INCH
LOWER LIMIT = 0 INCH
COUNT = 242

Figure 11. Histogram of Motor Nipple Lifting



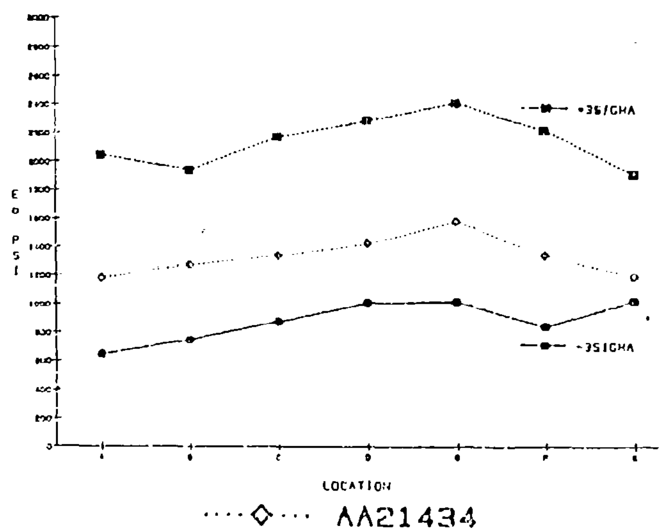
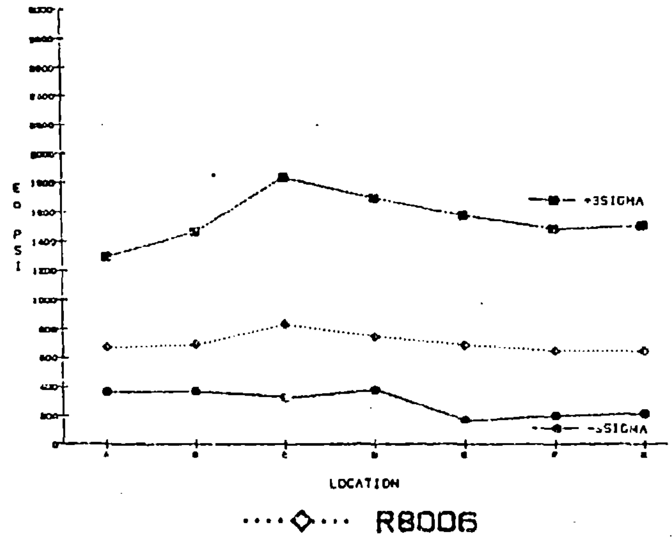
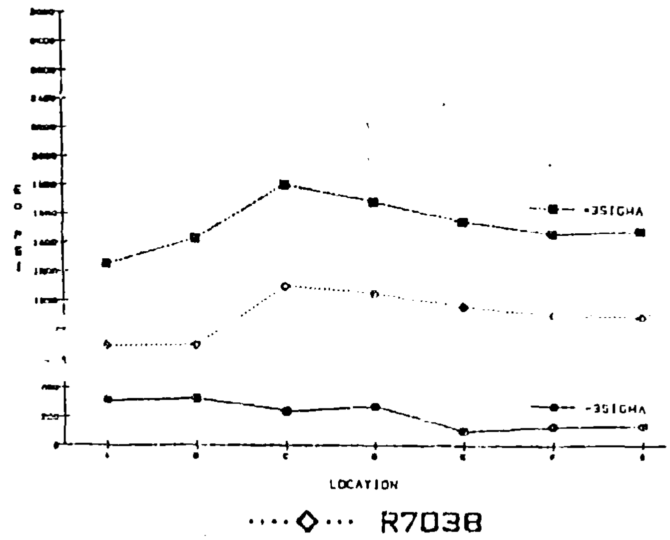


Figure 12. On-Surface Evaluation of Washout Motors; Initial Modulus vs Motor Axial Location

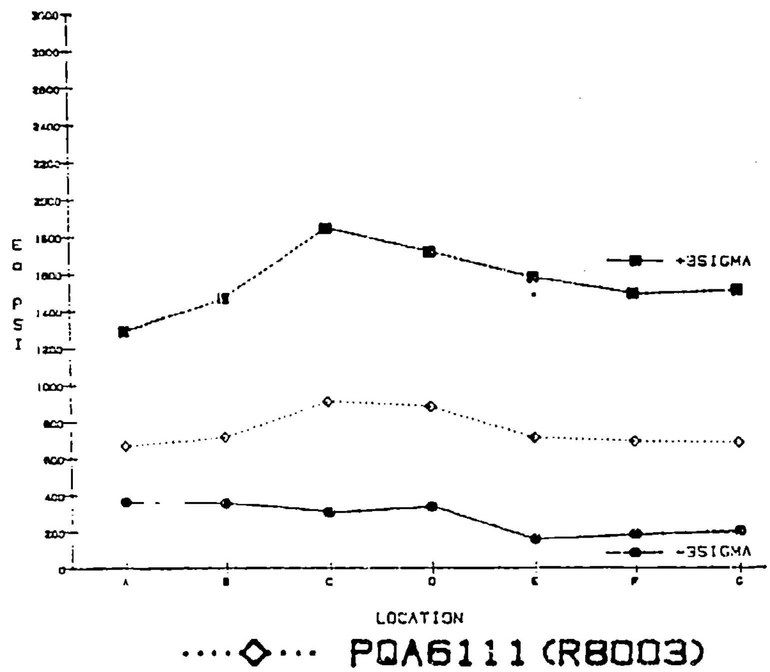


A

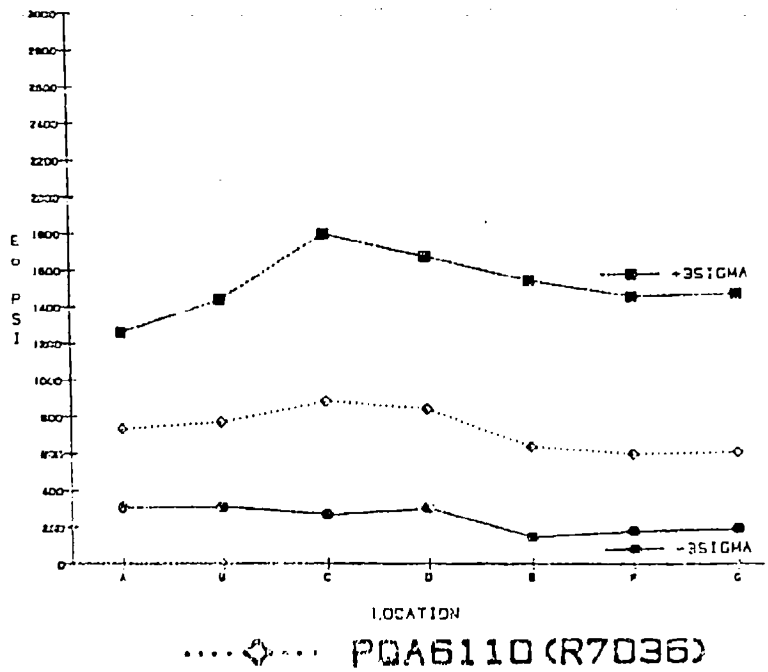


B

Figure 13. On-Surface Evaluation of Regrain Motors;
Initial Tangent Modulus vs Axial Location

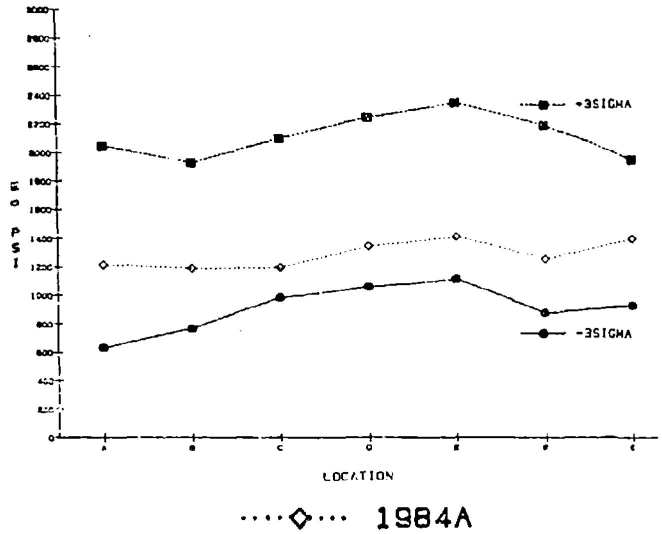


A

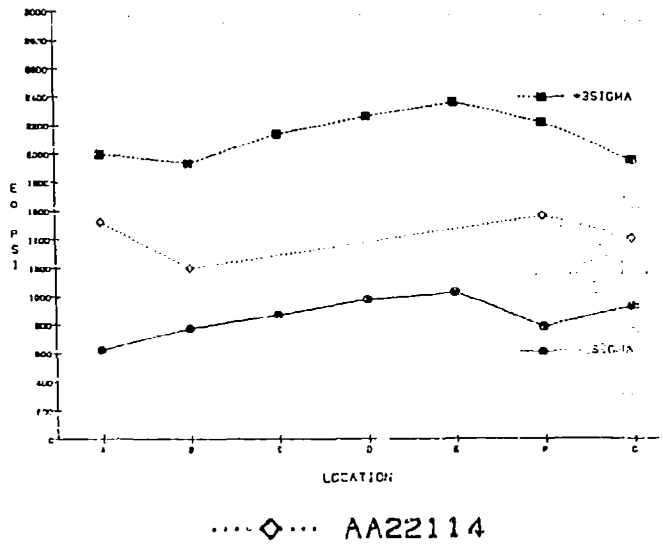


B

Figure 14. On-Surface Evaluation of PQA Motors; Initial Tangent Modulus vs Axial Location

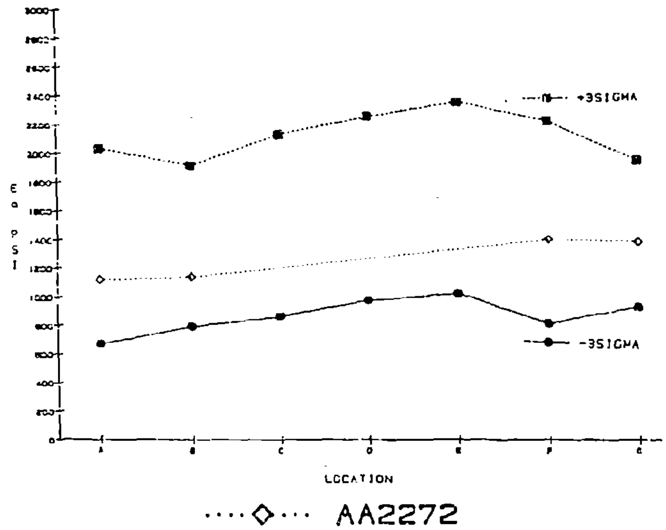


A

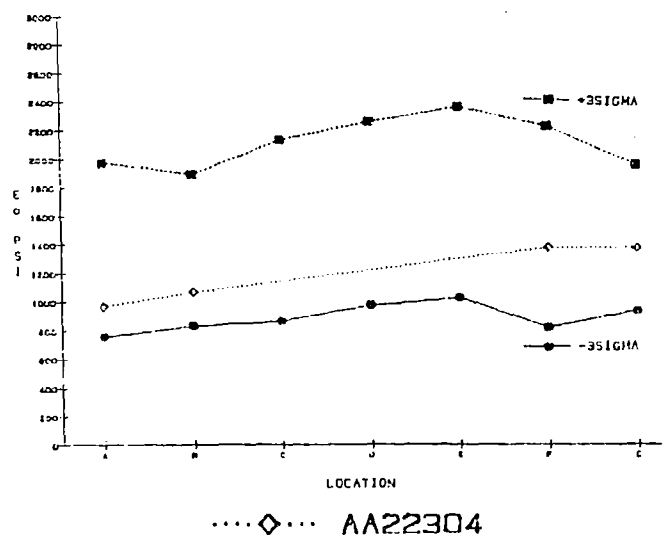


B

Figure 15. On-Surface Evaluation of Plug Motor 1984A and Hill AFB Tested Motors, Initial Tangent Modulus vs Axial Location, Sheet 1 of 2



C



D

Figure 15. On-Surface Evaluation of Plug Motor 1984A and Hill AFB Tested Motors, Initial Tangent Modulus vs Axial Location, Sheet 2 of 2

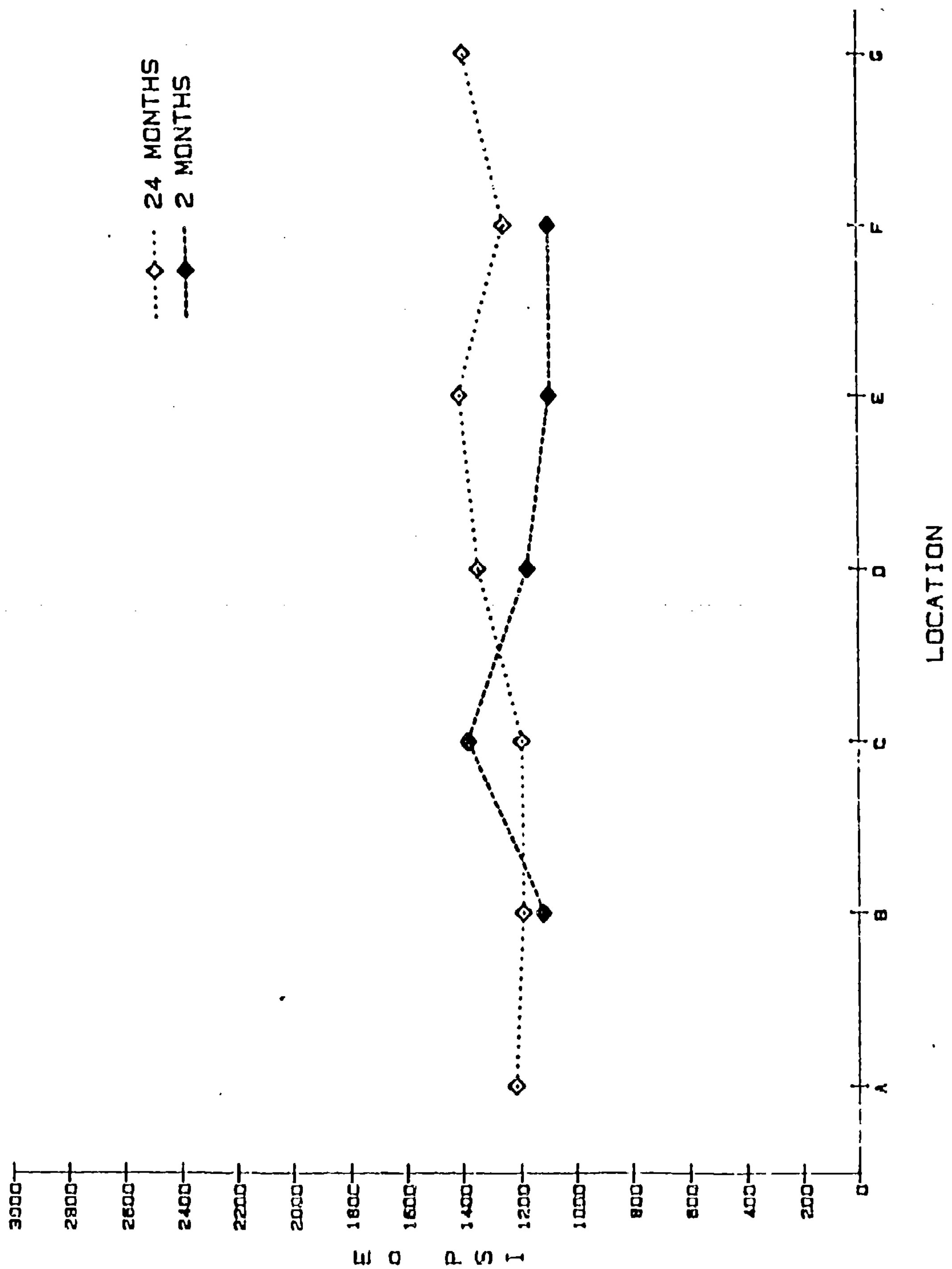


Figure 16. On-Surface Initial Tangent Modulus, E_o, of Motor MSEX-2 (1984A Plug Motor) at Ages 2 and 24 Mo

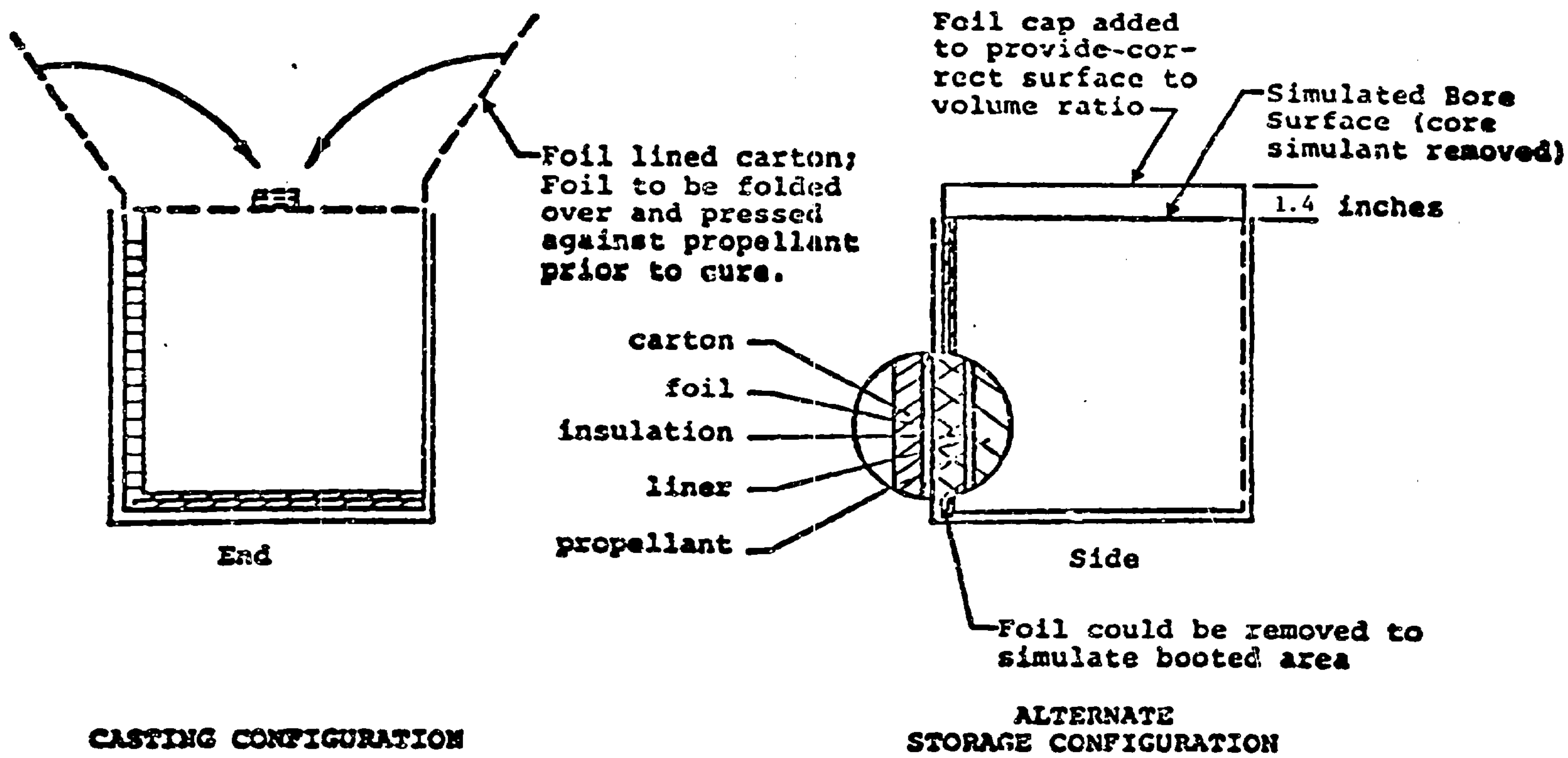


Figure 17. Configuration of Analog Aging Samples

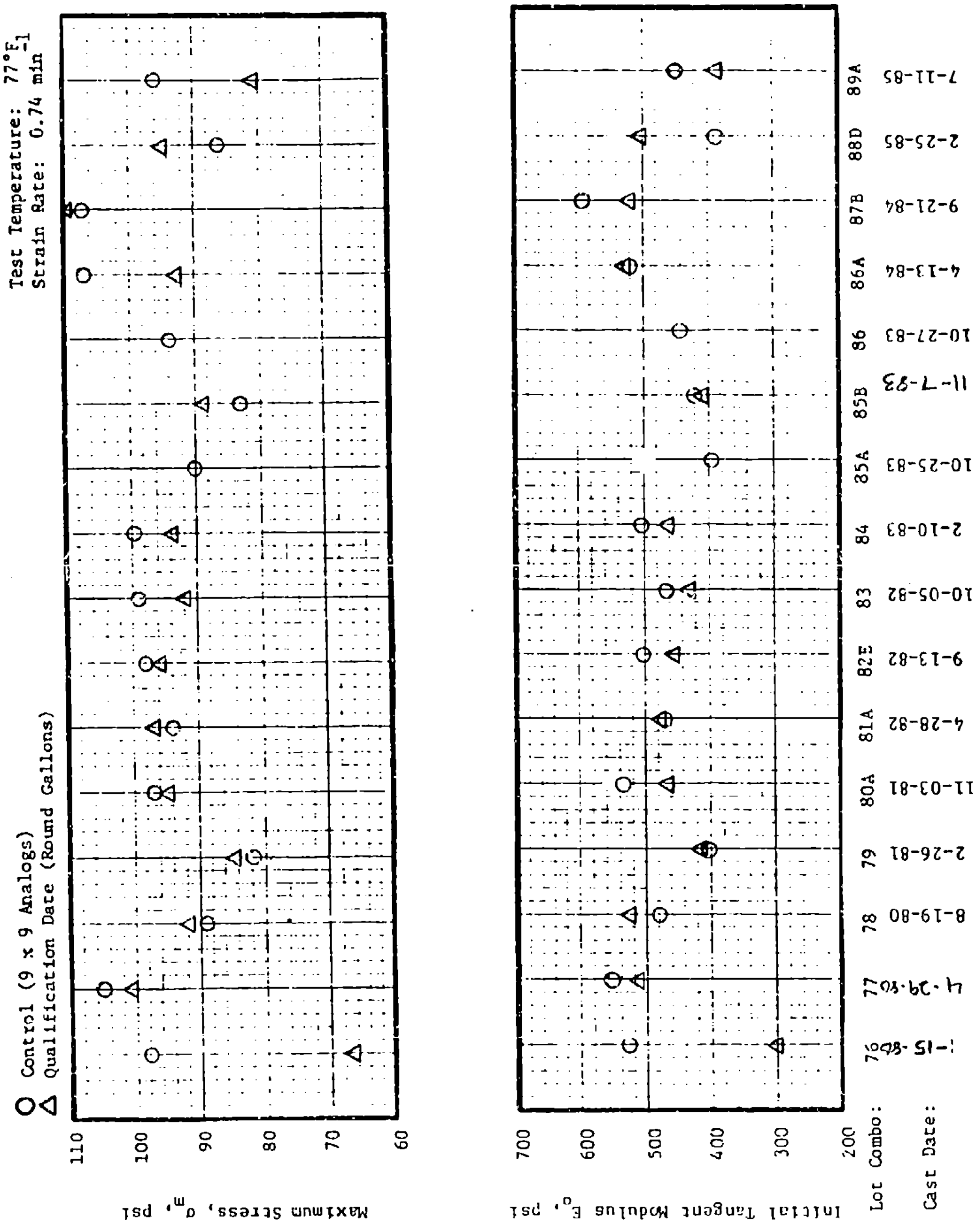


Figure 18. Configuration of Uniaxial Tensile Properties for Lot Combination 76 Through 89A, Unaged, Sheet 1 of 2

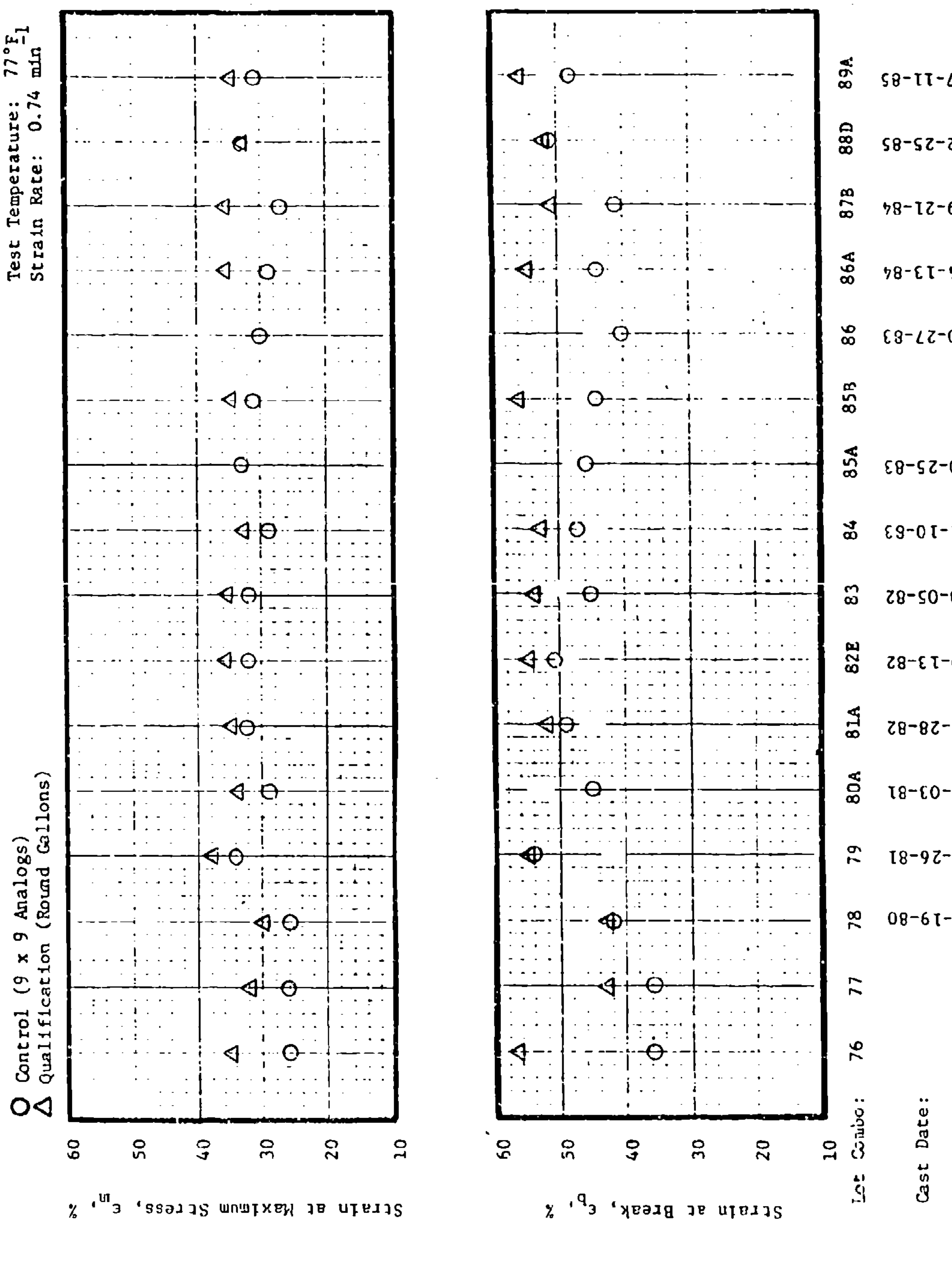


Figure 18. Configuration of Uniaxial Tensile Properties for Lot Combination 76 Through 89A, Unaged, Sheet 2 of 2

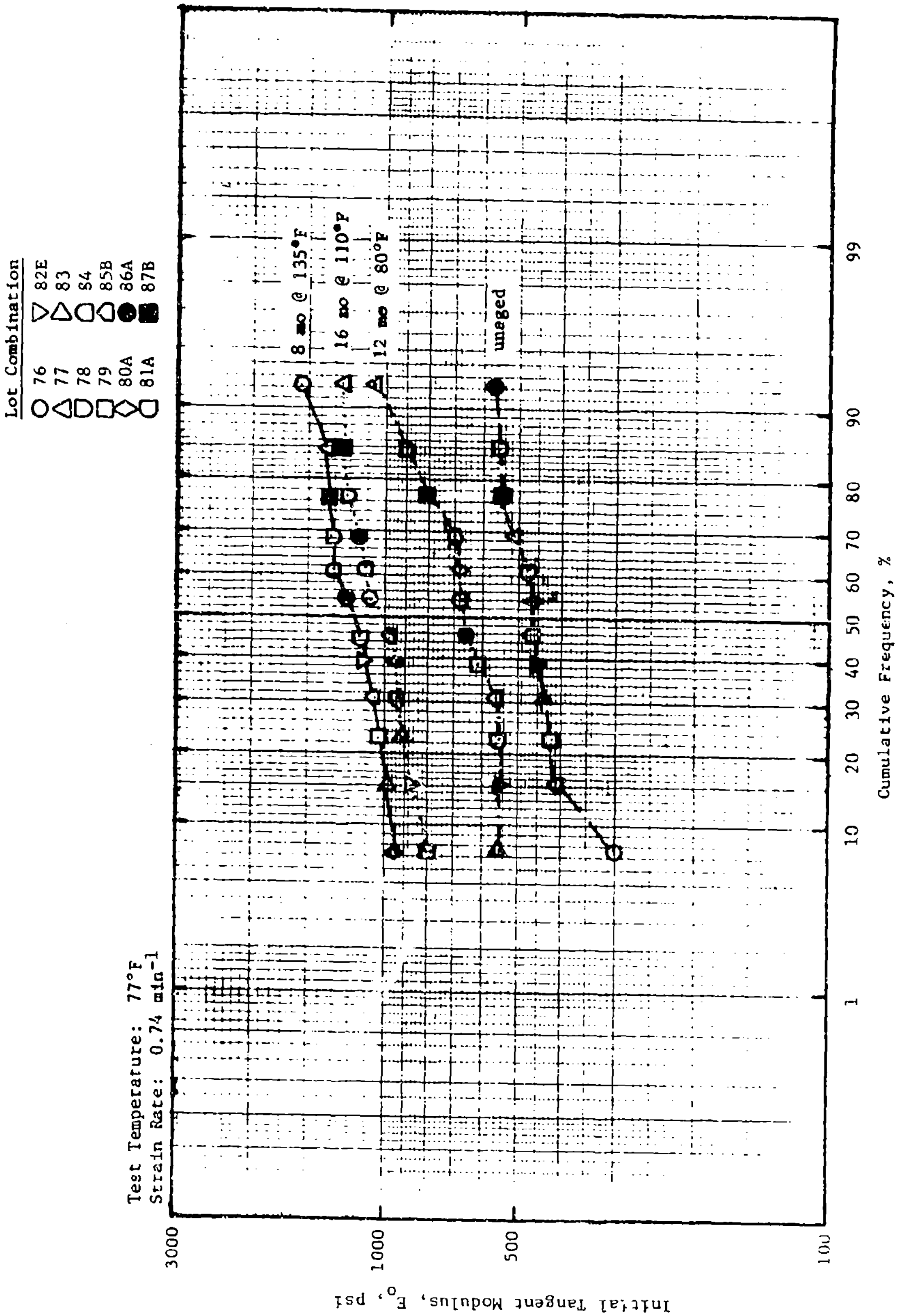
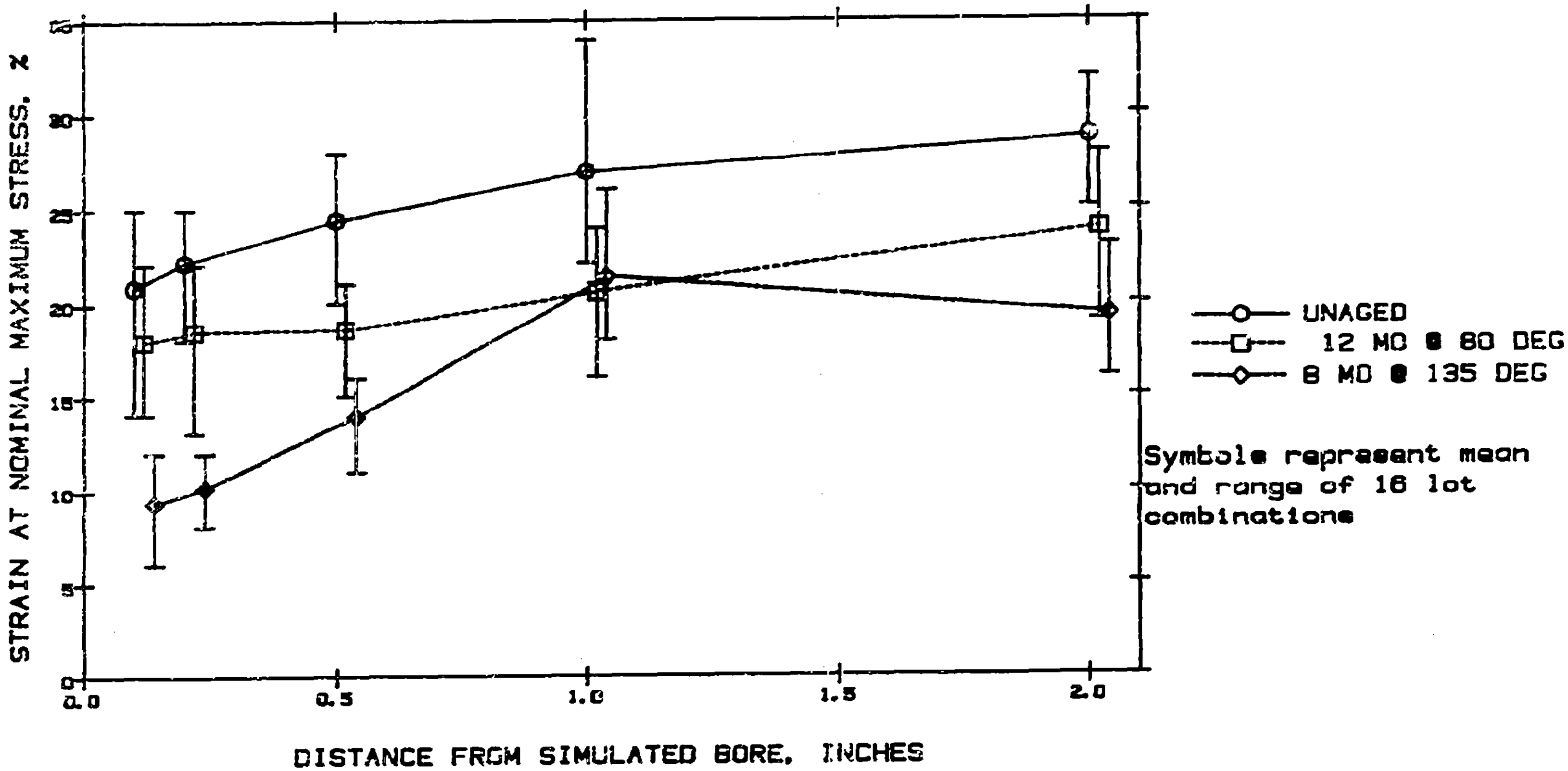
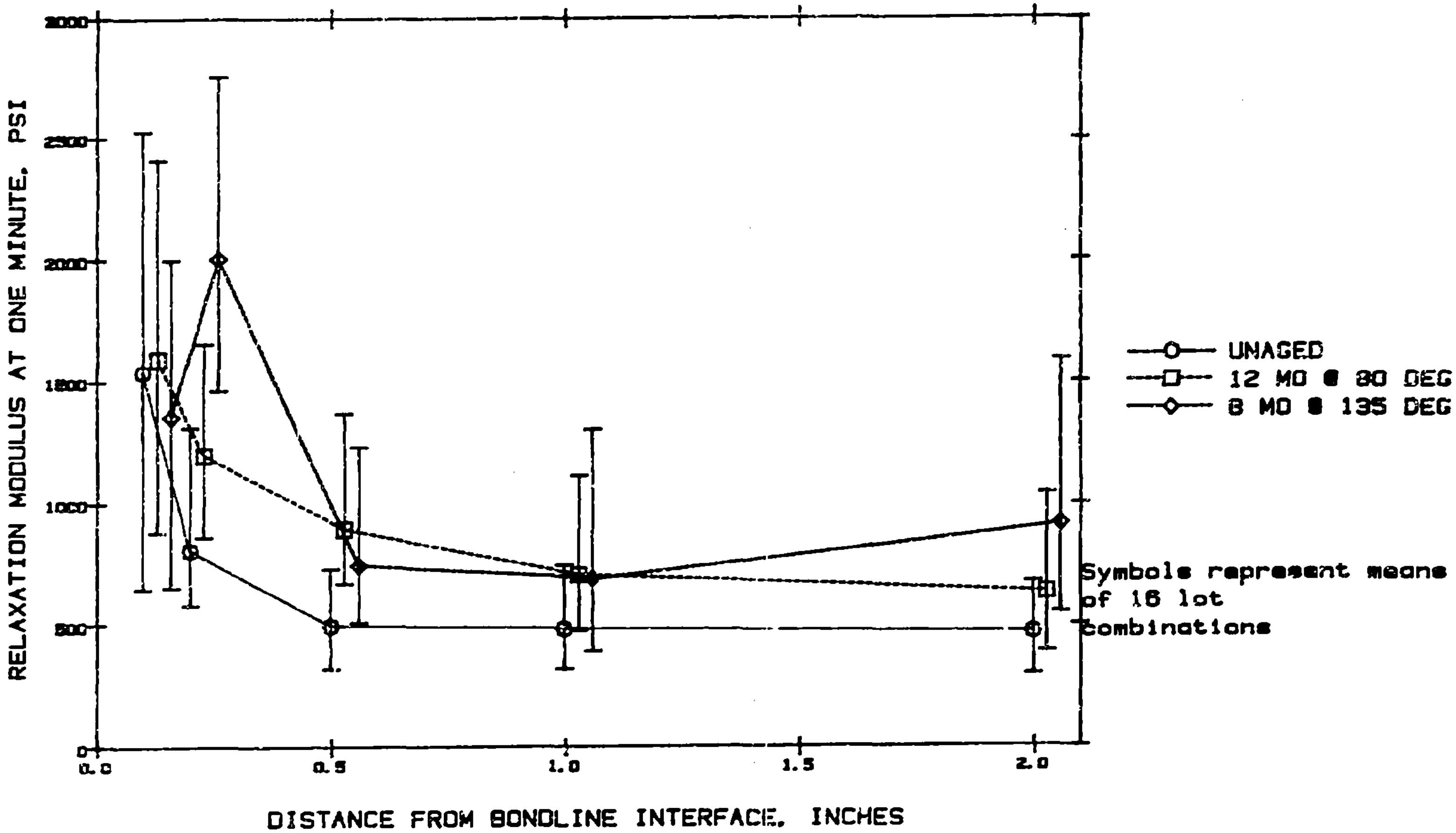


Figure 19. Effect of Aging on the Cumulative Frequency Distribution of Initial Tangent Modulus, ANB-3066 Propellant



Test Temperature: 77 Deg
Crosshead Rate: 1.0 in/min
Type Specimen: Mini Uniaxial Tensile

Figure 20. Effect of Distance from Simulated Bore on Strain Capability of ANB-3066 Propellant (Laboratory Samples)



Test Temperature: 77 Deg
Applied Strain: 2.0%

Figure 21. Effect of Distance from the Bondline on Relaxation Modulus of ANB-3066 Propellant (Laboratory Samples)

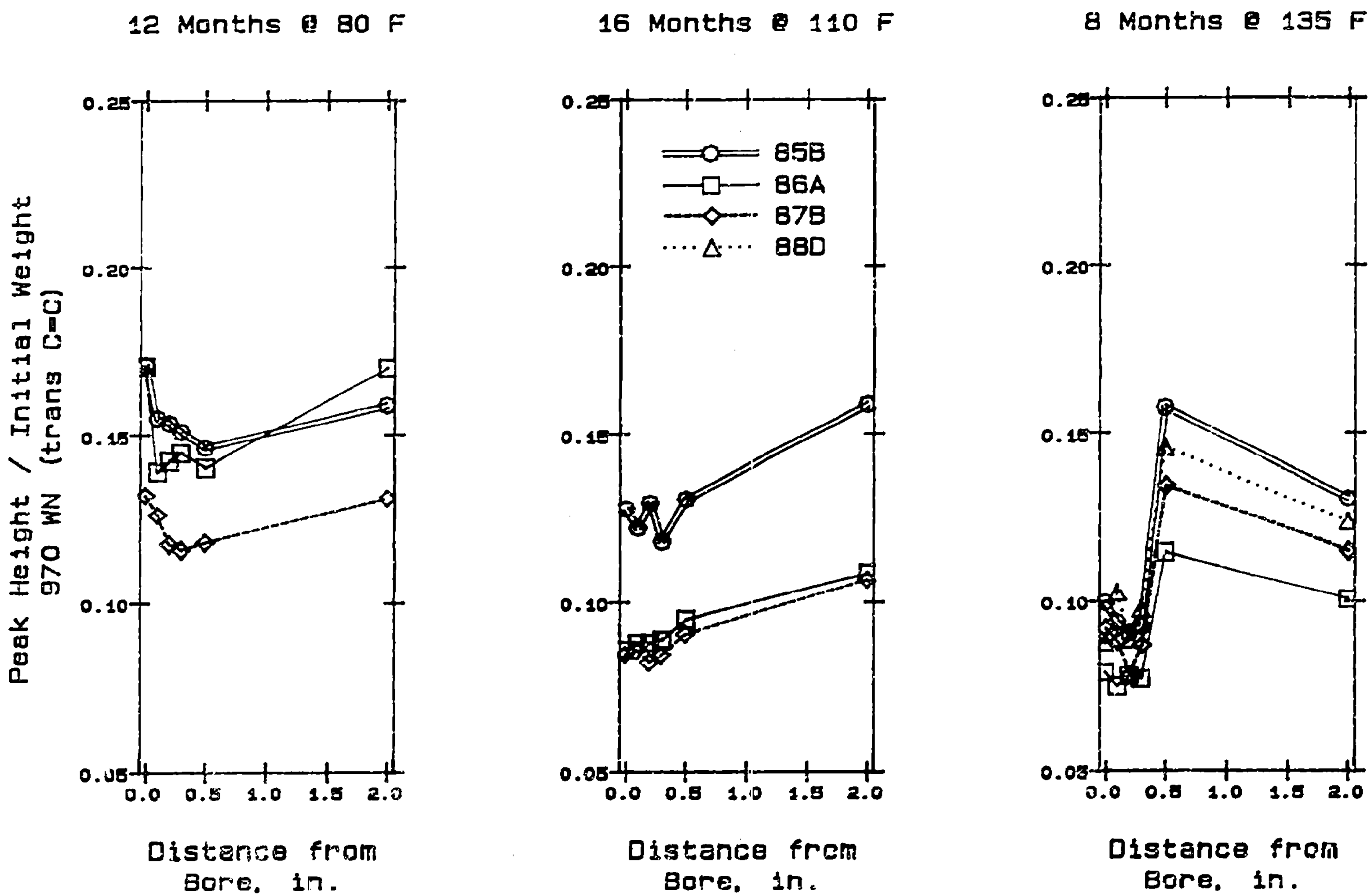


Figure 22. Comparison of Gradient Trends from Bore Surface of Analog Cartons by Amount of Extractable CTPB-Indicated by Height of 970 WN Peak

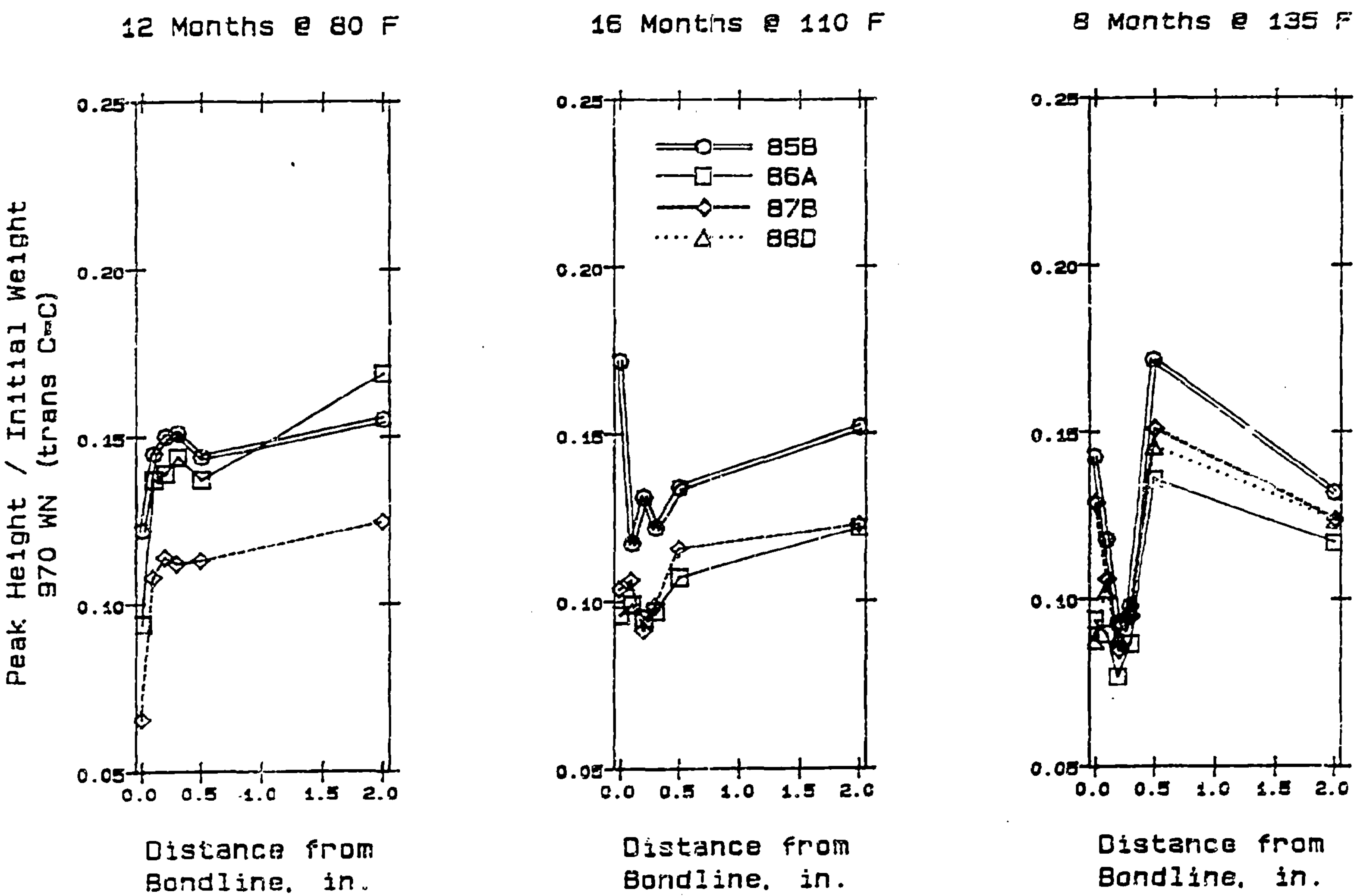
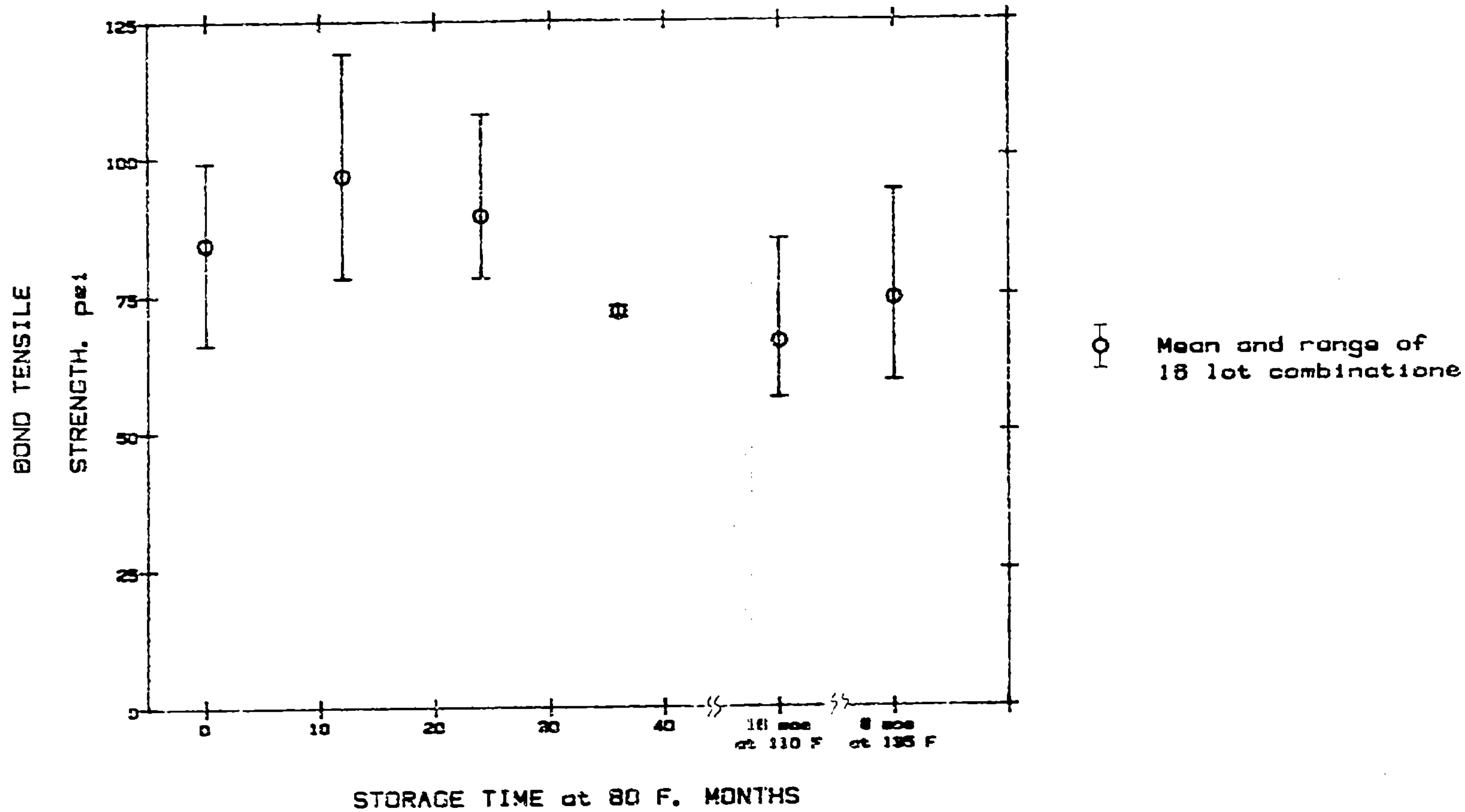


Figure 23. Comparison of Gradient Trends from Bondline Surface of Analog Cartons by Amount of Extractable CTPB - Indicated by Height of 970 WN Peak



Test Temperature: 77 Deg
Strain Rate: 1.0 min -1
Type Specimen: Double Plate Tensile

Figure 24. Effect of Aging on Bond Tensile Strength of ANB-3066/SD-851-2/V-45 Propellant-Liner-Insulation System (Analog Samples)

Test Temperature: 77°F
Crosshead Rate: 200 in./min
Superimposed Pressure: 600 psig

Lot Combo		Control	Bond Shear Strength, psi Following Aging at: 12 mo @ 80°F	24 mo @ 80°F	16 mo @ 110°F	8 mo @ 135°F	Aging Trend
80A				178			
82E			175		311		+
83			232		199		-
84			221		237	219	-
85A		220				243	+
85B		241	208		172	-	-
86		250				282	+
86A		272	222		234	170	-
87B		253	216			217	-
88D		253				205	-
89A		254					
	$\bar{X}$	249	212	178	231	223	
	s	15.8	19.9	-	52.3	37.6	
	s/$\bar{X}$, %	6.3	9.4	-	22.7	16.9	
	n	7	6	1	5	6	

Figure 25. Effect of Storage Conditions on Bond Shear Strength of ANB-3066/SD-851-2/V-45 Propellant-Liner-Insulation Bond

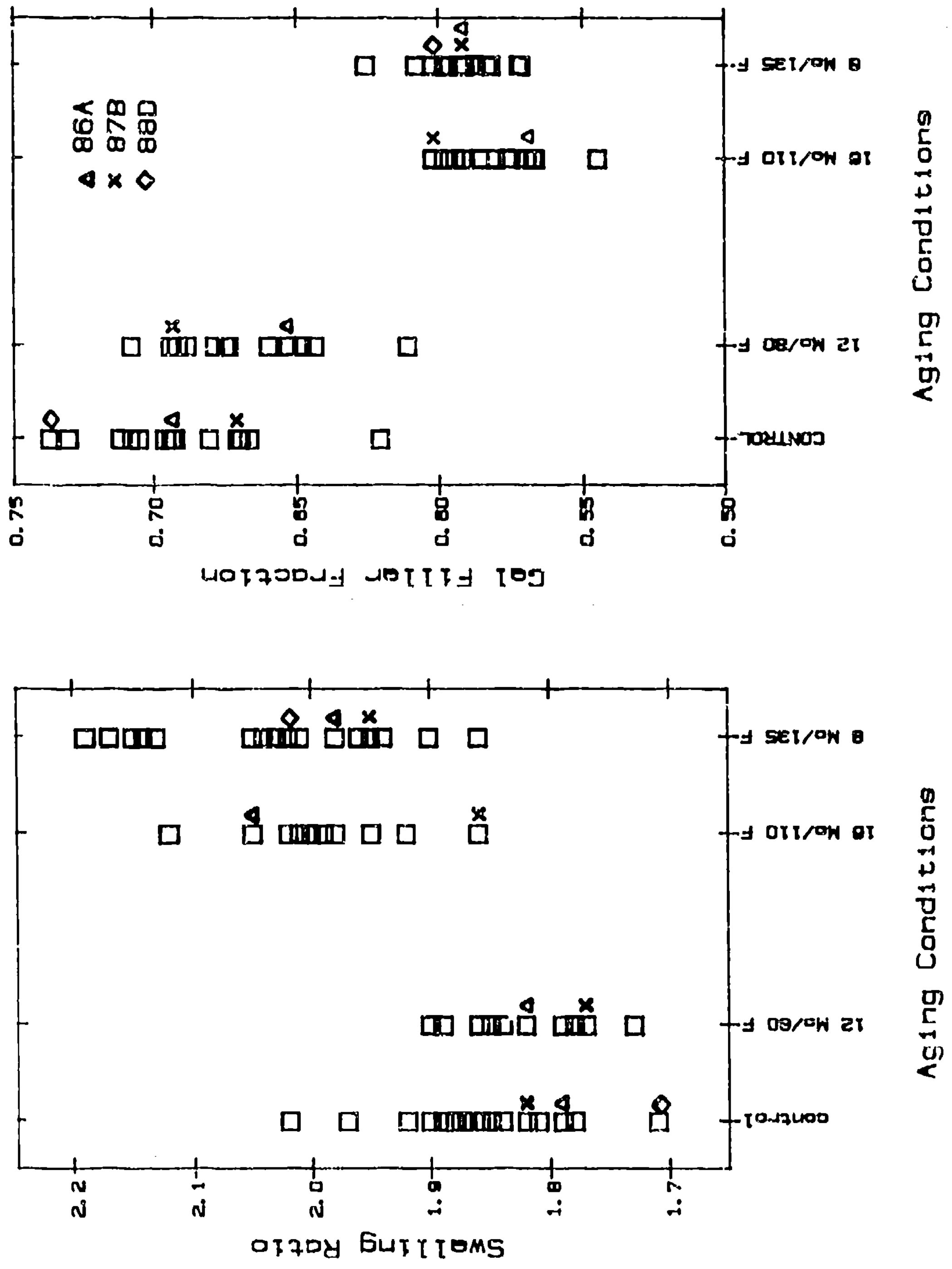


Figure 26. Chemical Properties of SD-851-2 Liner from Analog Cartons as a Function

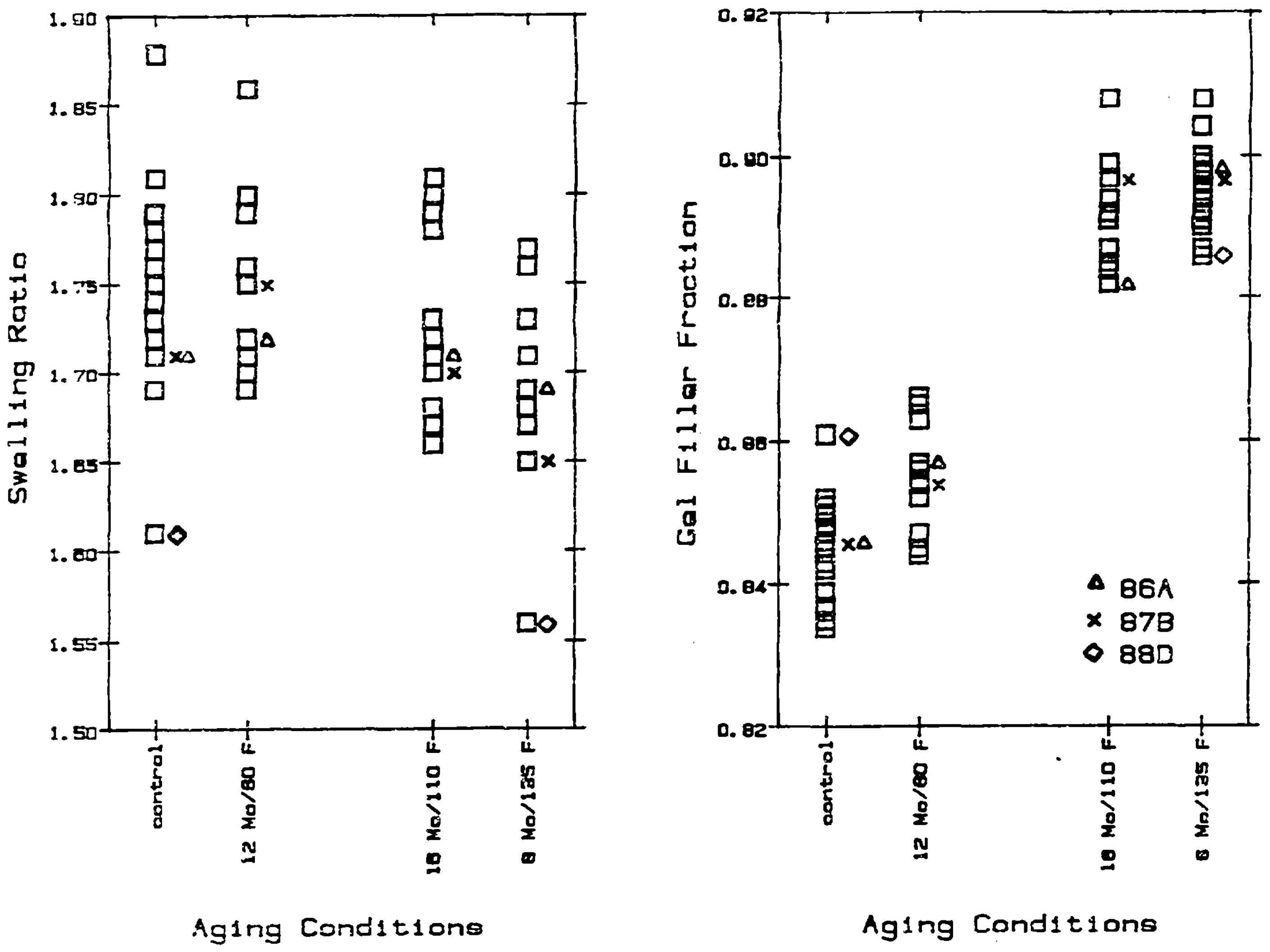


Figure 27. Chemical Properties of V-45 Insulation from Analog Cartons as a Function of Aging Conditions, Sheet 1 of 2

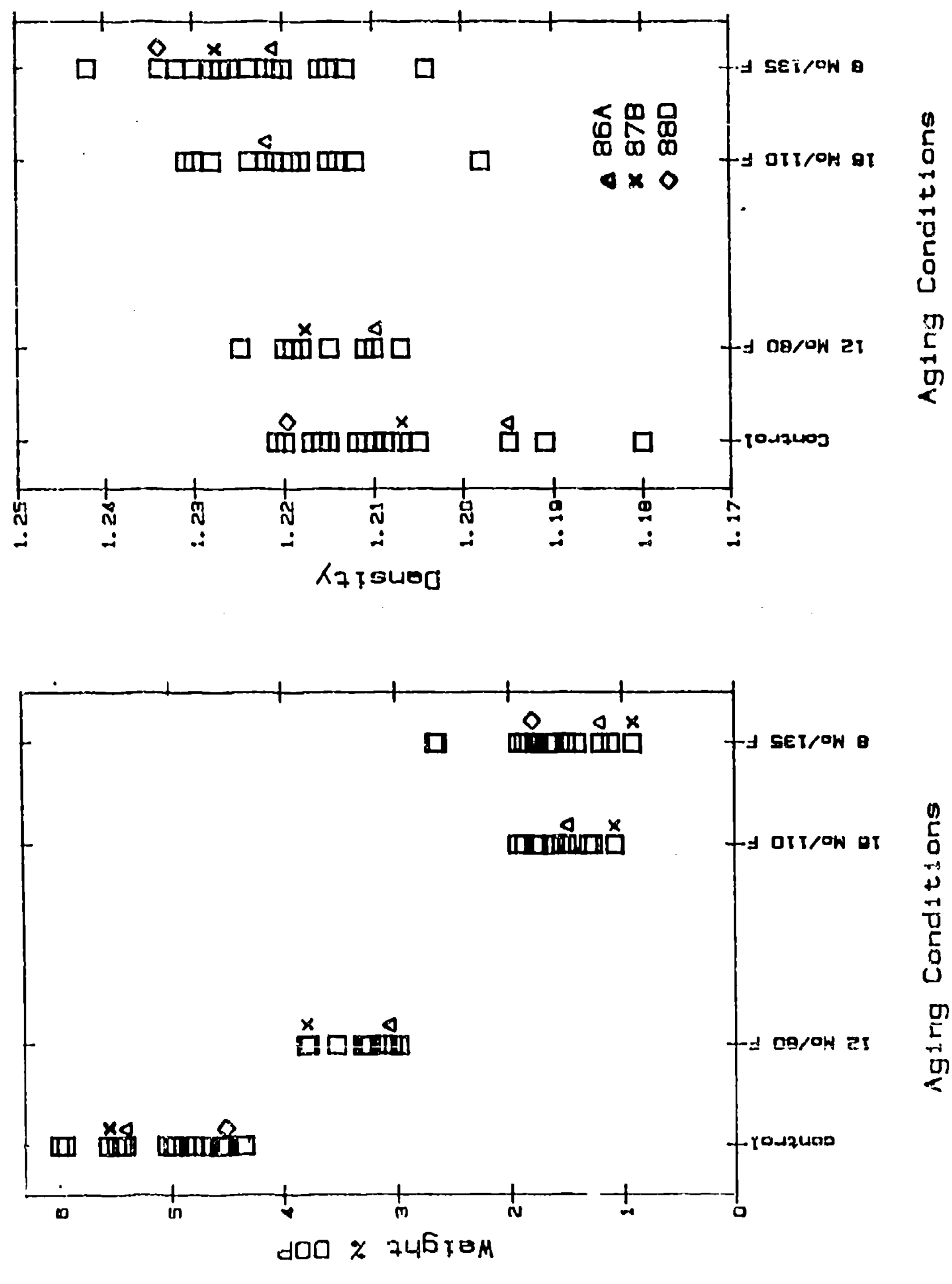


Figure 27. Chemical Properties of V-45 Insulation from Analog Cartons as a Function of Aging Conditions, Sheet 2 of 2

Test Interval Years	0	0.5	1	2	3	4	6	8	10	12	Total
. Plugs Tested											
Forward Barrel	X	X	X		X	X	X		X	X	8
Mid-Barrel	X(1)		X	X		X	X	X		X	8
Aft Barrel	X	X		X	X	X		X	X	X	8
. Excised Tested	X		X			X		X		X	5
. Bore Tested	X		X			X		X		X	5
. NDT tests											
Bondline	X		X			X		X		X	5
Surface	X		X			X		X		X	5
Ignition Delay	X		X			X		X		X	5
. Analog Tests(2)	X(3)		X	X		X		X		X(3)	10
Ignition Delay	X(3)		X	X		X		X		X(3)	10

(1) 30 and 210° plugs
(2) Third batch only 1984A Motor Only
(3) Three batches 1984A Motor Only

Figure 28. Test Schedule for Plugged Stage II Motor

Type Sample	Sample Location	Area of Concern	Objectives
Excise	Aft End	Bore, Bondline	. Determine aging trends in aft end
			. Compare properties of plug motor with data from population of full-scale motors (n = 113)
Bore	Aft Bore	Bore	. Evaluate surface hardening at the bore
			. Compare with data from full-scale motors (n = 25)
Plugs	Chamber	Bulk (to 4 in.), Bondline	. Identify changes in bond and propellant properties due to aging
			. Evaluate effect of sample location (forward, mid-barrel, aft chamber, aft end)
Analogs		Simulated Bore, Bulk, Simulated Bondline	. Evaluate motor/carton bias
			. Compare aging behavicr with population of analog samples (n = 16)

Figure 29. Summary of Testing Objectives for Samples Removed from the Plug Motor

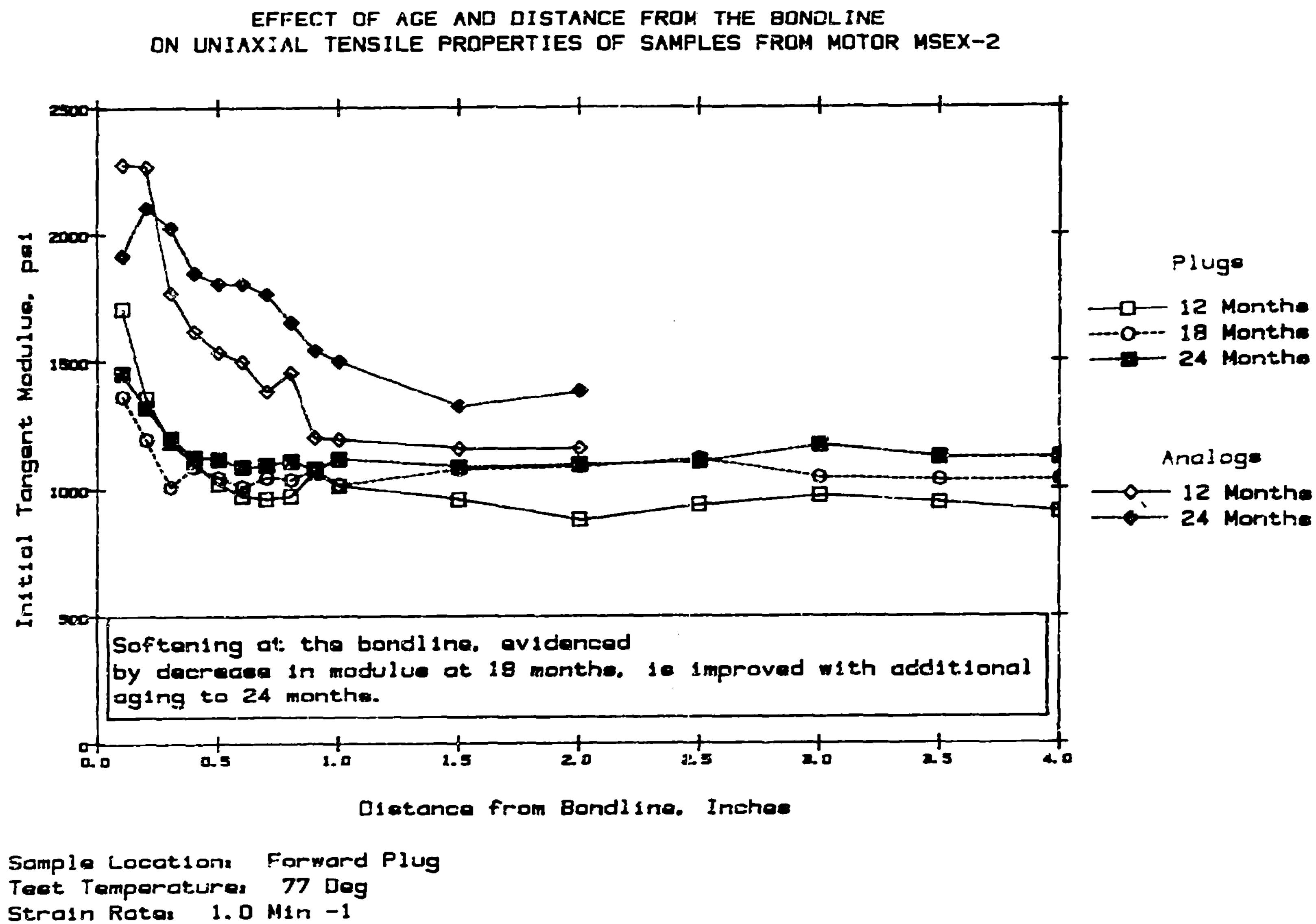


Figure 30. Effect of Age and Distance from the Bondline on Uniaxial Tensile Properties of Samples from Motor MSEX-2

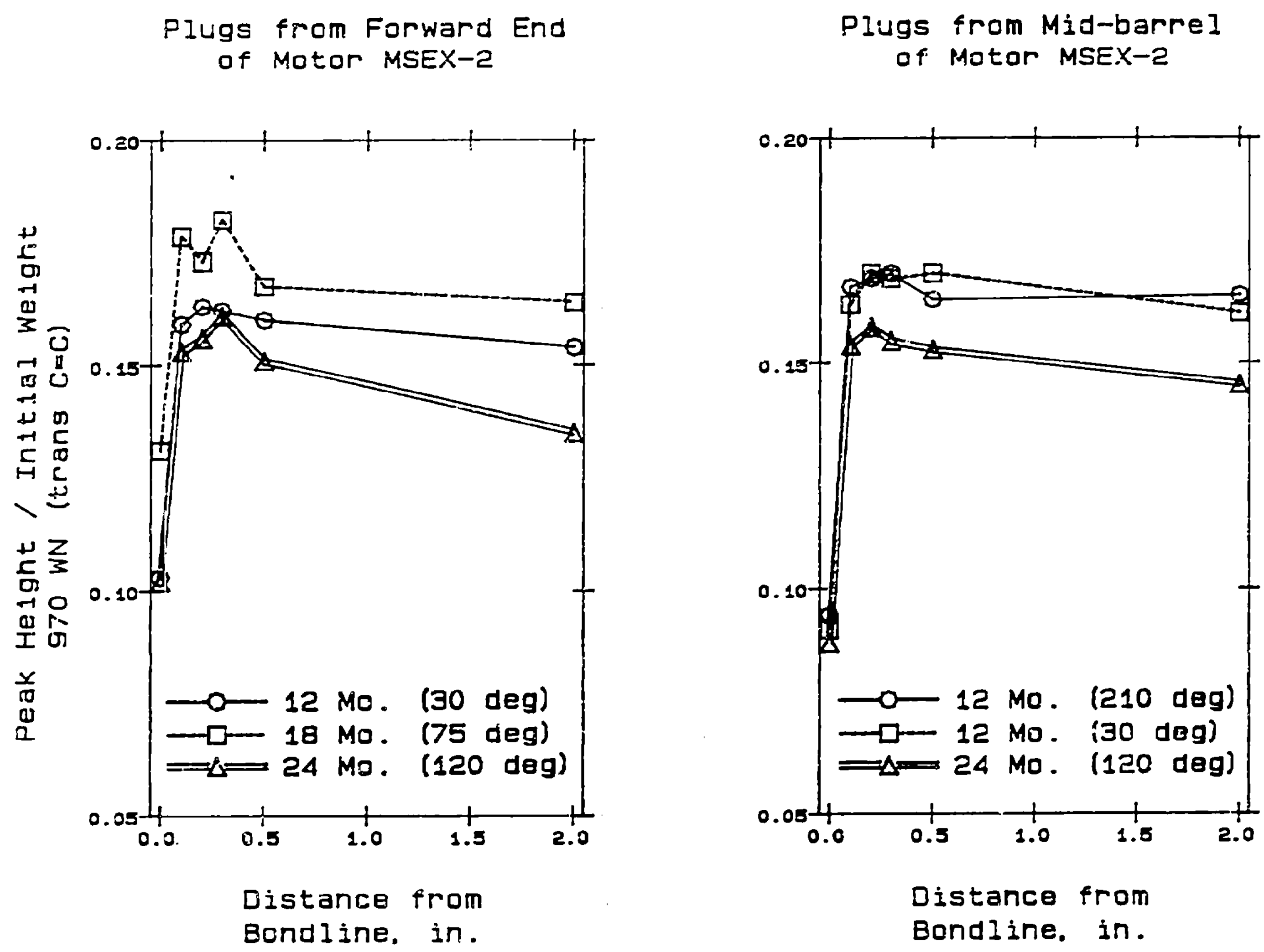


Figure 31. Amount of Extractable CTPB Indicated by Height of 970 WN Peak; Gradient Trends from Bondline Surface of Forward and Mid-Barrel Plugs from Motor MSE

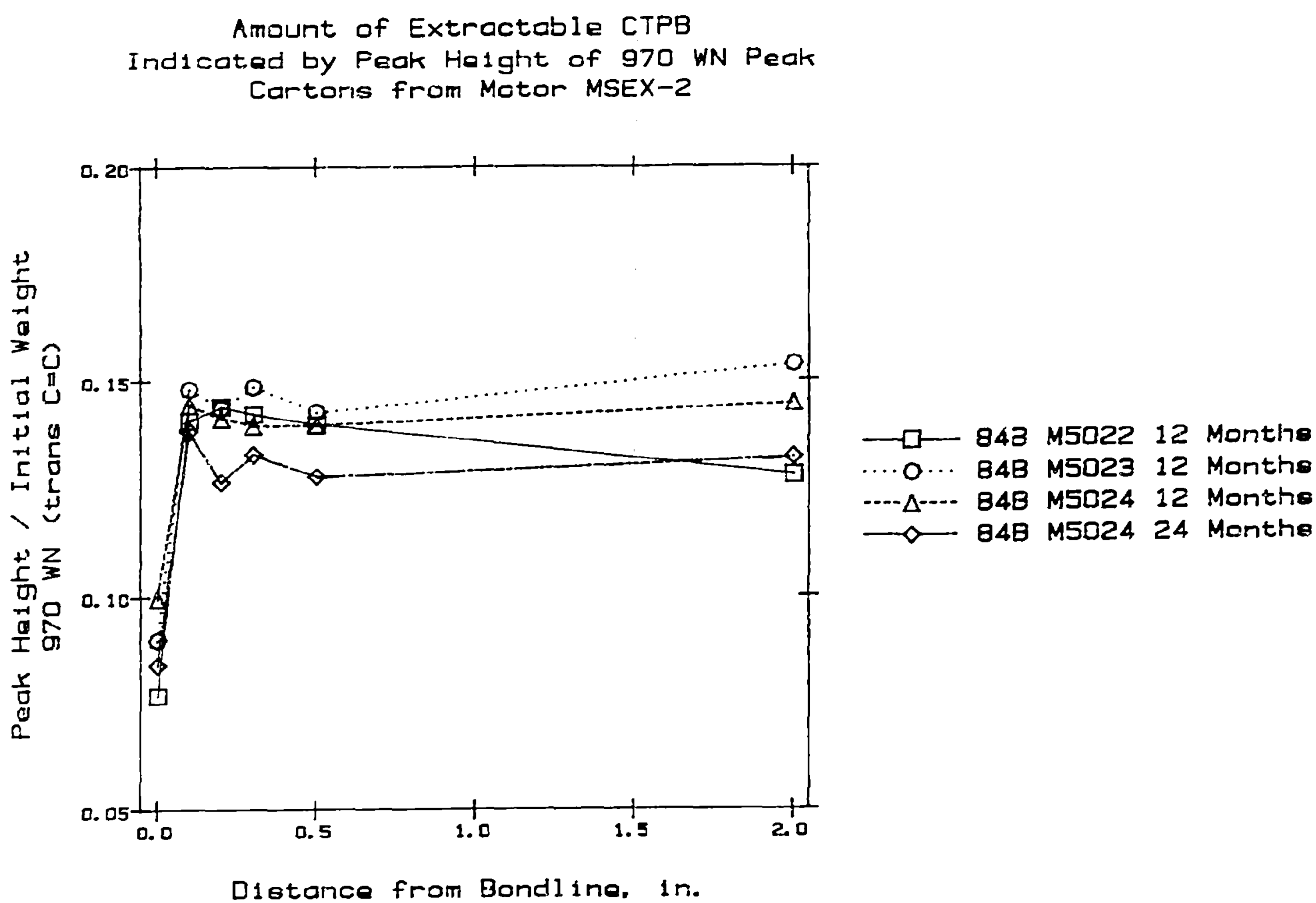


Figure 32. Amount of Extractable CTPB Indicated by Peak Height of 970 WN Peak
(Cartons from Motor MSEX-2)

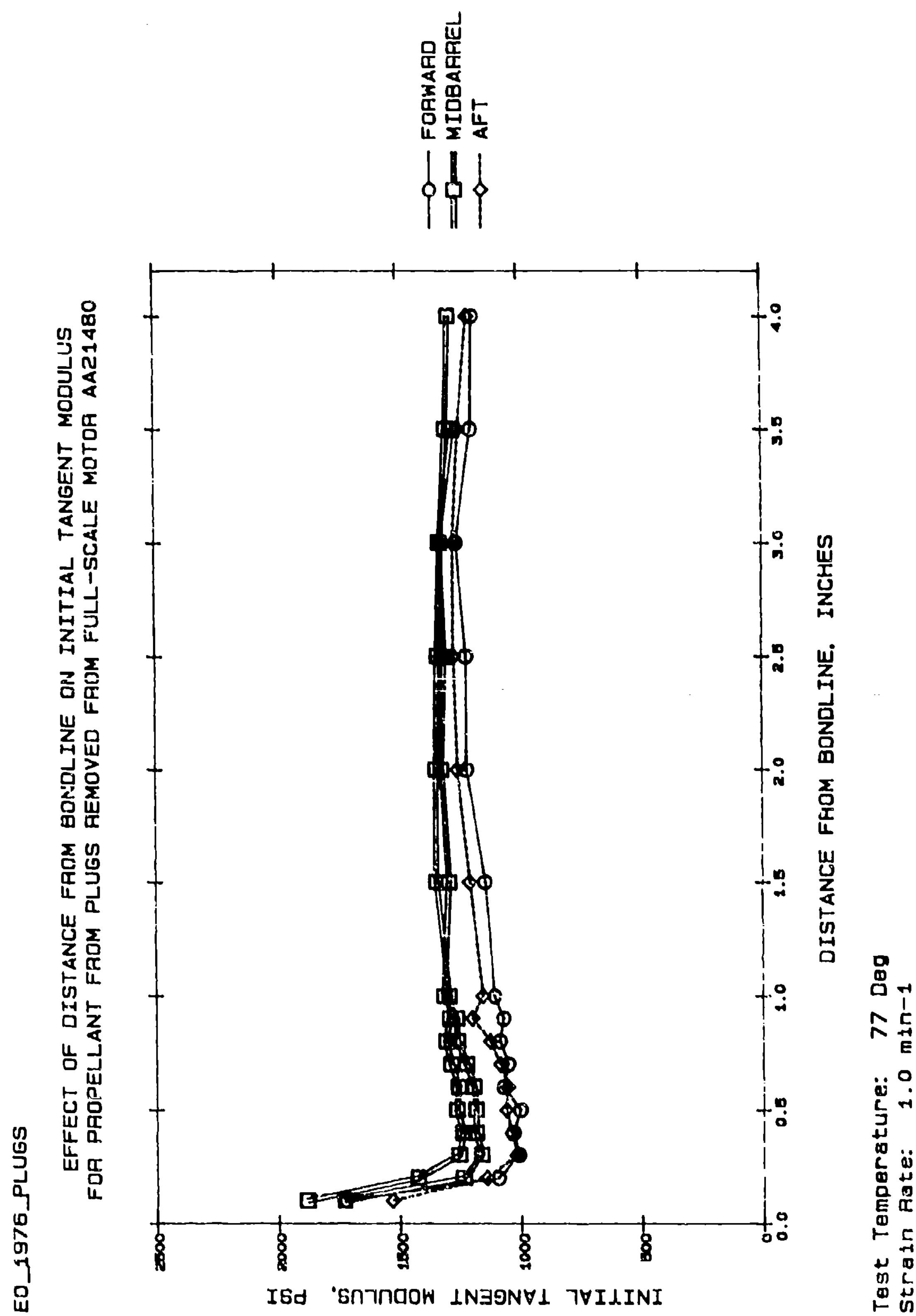


Figure 33. Effect of Distance from Bondline on Initial Tangent Modulus for Propellant from Plugs Removed from Full-Scale Motor AA21480 (1976A)

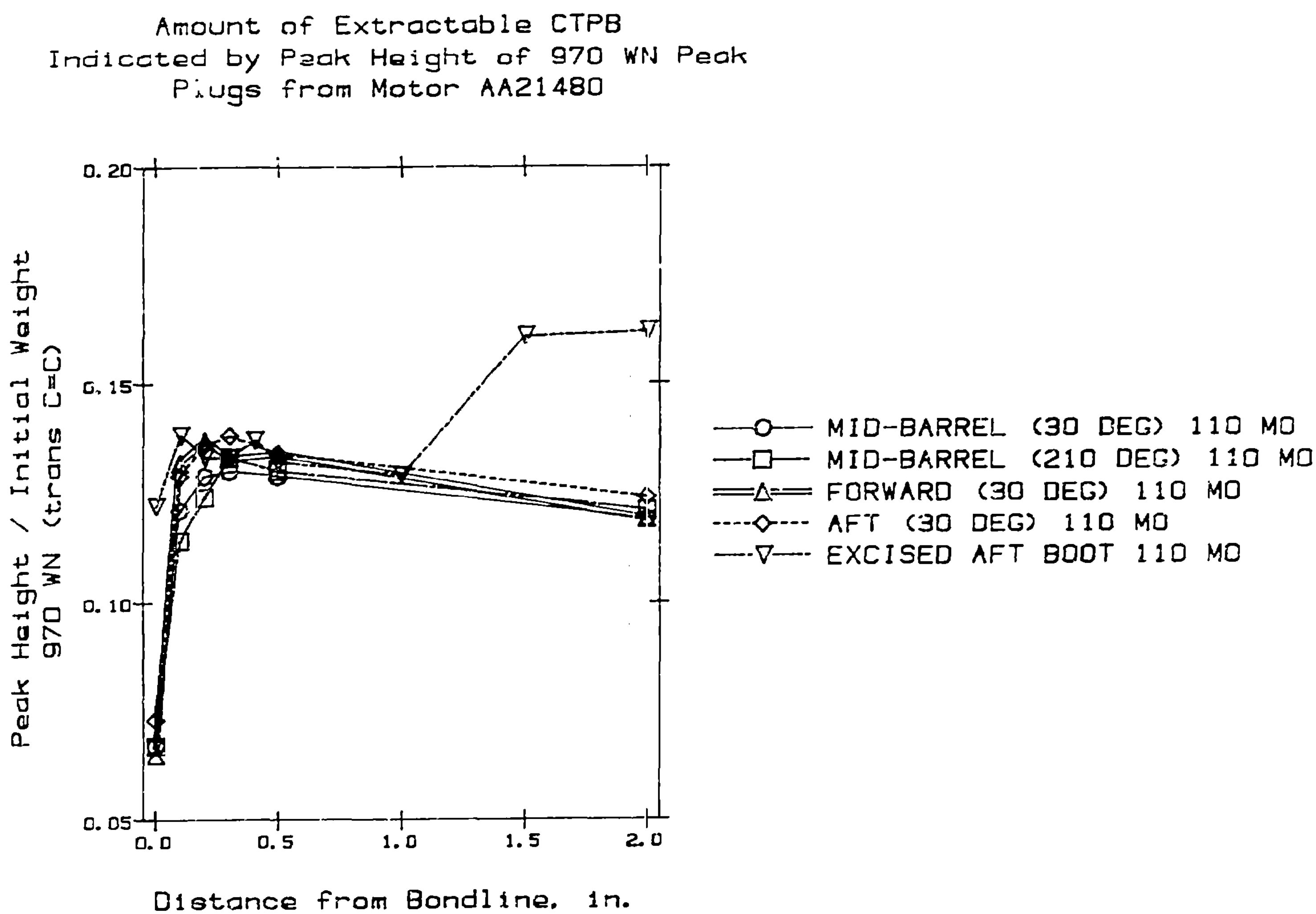


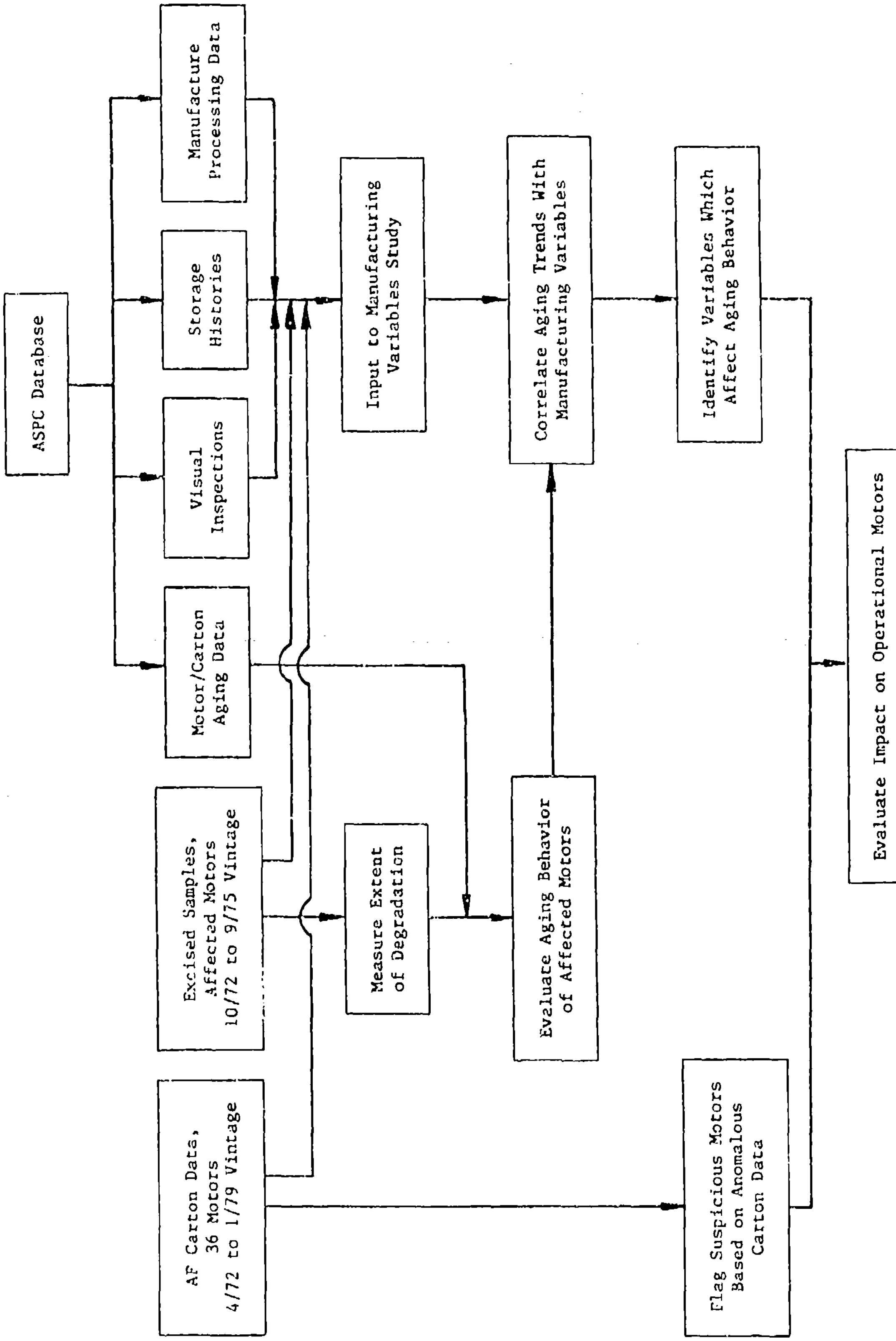
Figure 34. Amount of Extractable CTPB Indicated by Peak Height of 970 WN Peak Plugs from Motor AA21480

Sample Location (Deg)		Bond Tensile Strength @ 77°F, 0.5 in./min — Stress, psi	Time to Fail, min	Type Failure, % CP	APL	CL	ALI	F		Bond Shear Strength @ 77°F, 200 in./min, 600 psig — Stress, psi	Time to Fail, sec	Type Failure, % CP	APL	CL	ALI	F
Forward (30)		98	0.104		50	50				214	0.117		25	75		
		107	0.102		50	50				214	0.147		40	60		
	$\bar{X}$	102	0.103						$\bar{X}$	214	0.132					
Mid-barrel (30)		112	0.085		70	30				273	0.086		25	75		
		114	0.092		75	25				266	0.080		50	50		
	$\bar{X}$	113	0.090						$\bar{X}$	269	0.083					
(210)		108	0.096		70	30				264	0.085		40	60		
		121	0.093		65	35				256	0.086		40	60		
	$\bar{X}$	114	0.094						$\bar{X}$	260	0.086					
Aft (30)		95	0.111		100					235	0.104		40	60		
		105	0.100		100					214	0.121		40	60		
	$\bar{X}$	100	0.105						$\bar{X}$	224	0.112					
Aft End (Excise)		45	0.40		90	10										
		54	0.56		95	5										
		33	0.37		10	30	60									
	$\bar{X}$	44	0.44													

Figure 35. Summary of Bond Testing Conducted on Plugs Removed from Motor AA2148C (1976A)

Motor No.	Storage Location	Manufacturing Date	Liner Lot	Sampling: Complete	Sampling: Pending
AA21046	Silo	10-72	L_f		X
AA21049	Silo	10-72	L_f	X	
AA21051	Silo	10-72	L_f	X	
AA21058	Silo	10-72	L_f		X
AA21067	Silo	10-72	L_f		X
AA21111	Silo	2-73	L_f		X
AA21123	Silo	3-73	L_f		X
AA21321	Silo	7-74	S_q	X	
AA21342	Silo	8-74	S_q		X
AA21434	Lakeside	9-75	Z_s	X	
AA21436	Lakeside	9-75	Z_s		X

Figure 36. Summary of OO-ALC Rejected Motors



Logic Diagram for Early Age-Out Program

Figure 37. Logic Diagram for Early Age-Out Program

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	IGNITER S/N	DELAY MILLISEC	DURATION SEC	AVG PRES PSI	MAX PRES. PSI	Pdt PSI/SEC	AGE MON.	DATE FIRED	LOT	FIRED FOR	REMARKS
31	2026391	9.0	0.280	1036	1193	290.0	239	9-85	16	VECP	
34	2026395	10.0	0.279	1042	1255	290.8	238	8-85	16	VECP	
39	2026434	6.0	0.272	1075	1317	292.0	239	9-85	18	VECP	UNSEALED
40	2026437	9.0	0.279	1056	1170	294.5	238	8-85	18	VECP	UNSEALED
50	2026481	7.0	0.285	1030	1182	293.5	237	8-85	20	VECP	UNSEALED
51	2026492	8.0	0.292	991	1133	289.0	247	4-86	20	VECP/AGING	
52	2026494	19.0	0.287	1022	1160	293.3	237	8-85	20	VECP	UNSEALED
53	2026508	8.0	0.281	1093	1118	293.0	236	8-85	21	VECP	UNSEALED
54	2026514	5.0	0.278	1053	1179	293.0	237	9-85	21	VECP	UNSEALED
55	2026539	18.0	0.286	1024	1112	293.0	231	9-85	22	VECP	UNSEALED
57	2026663	9.0	0.283	1063	1198	300.8	231	8-85	27	VECP	UNSEALED
58	2026664	10.0	0.285	1018	1177	290.0	232	9-85	27	VECP	UNSEALED
60	2026787	17.0	0.275	992	1167	272.8	227	8-85	32	VECP	UNSEALED
63	2026789	18.0	0.279	975	1102	272.0	227	8-85	32	VECP	UNSEALED
65	2026984	10.0	0.256	1042	1204	267.0	236	3-86	36	VECP/AGING	
66	2026890	10.0	0.251	1079	1301	271.0	236	3-86	36	VECP/AGING	
72	2027033	10.0	0.279	962	1073	269.0	228	4-86	42	VECP/AGING	
73	2027039	21.0	0.276	968	1067	267.0	221	9-85	42	VECP	UNSEALED
74	2027046	17.0	0.277	993	1117	275.0	221	9-85	42	VECP	UNSEALED
77	2027084	13.0	0.281	1060	1170	298.0	217	9-85	44	VECP	UNSEALED
79	2027141	16.0	0.271	1022	1122	277.0	214	9-85	46	VECP	UNSEALED
80	2027177	11.0	0.292	1003	1081	293.0	216	3-86	48	VECP/AGING	
81	2027186	12.0	0.298	973	1062	290.0	216	3-86	48	VECP/AGING	
83	2027330	20.0	0.277	962	1041	266.0	195	1-86	54	VECP	UNSEALED
94	2027332	15.0	0.279	971	1071	271.0	195	1-86	54	VECP	2ES
85	2027333	15.0	0.278	981	1095	273.6	190	8-85	54	VECP	UNSEALED
86	2027334	15.0	0.278	975	1083	271.0	195	1-86	54	VECP	UNSEALED
87	2027337	19.0	0.271	1008	1114	273.2	190	8-85	54	VECP	UNSEALED
98	2027338	15.0	0.280	960	1062	269.0	195	1-86	54	VECP	2HS
99	2027340	14.0	0.282	973	1060	274.0	195	1-86	54	VECP	2HS
90	2027342	10.0	0.281	982	1105	276.0	195	1-86	54	VECP	UNSEALED

Figure 38. Summary of Igniter VECP Test Results

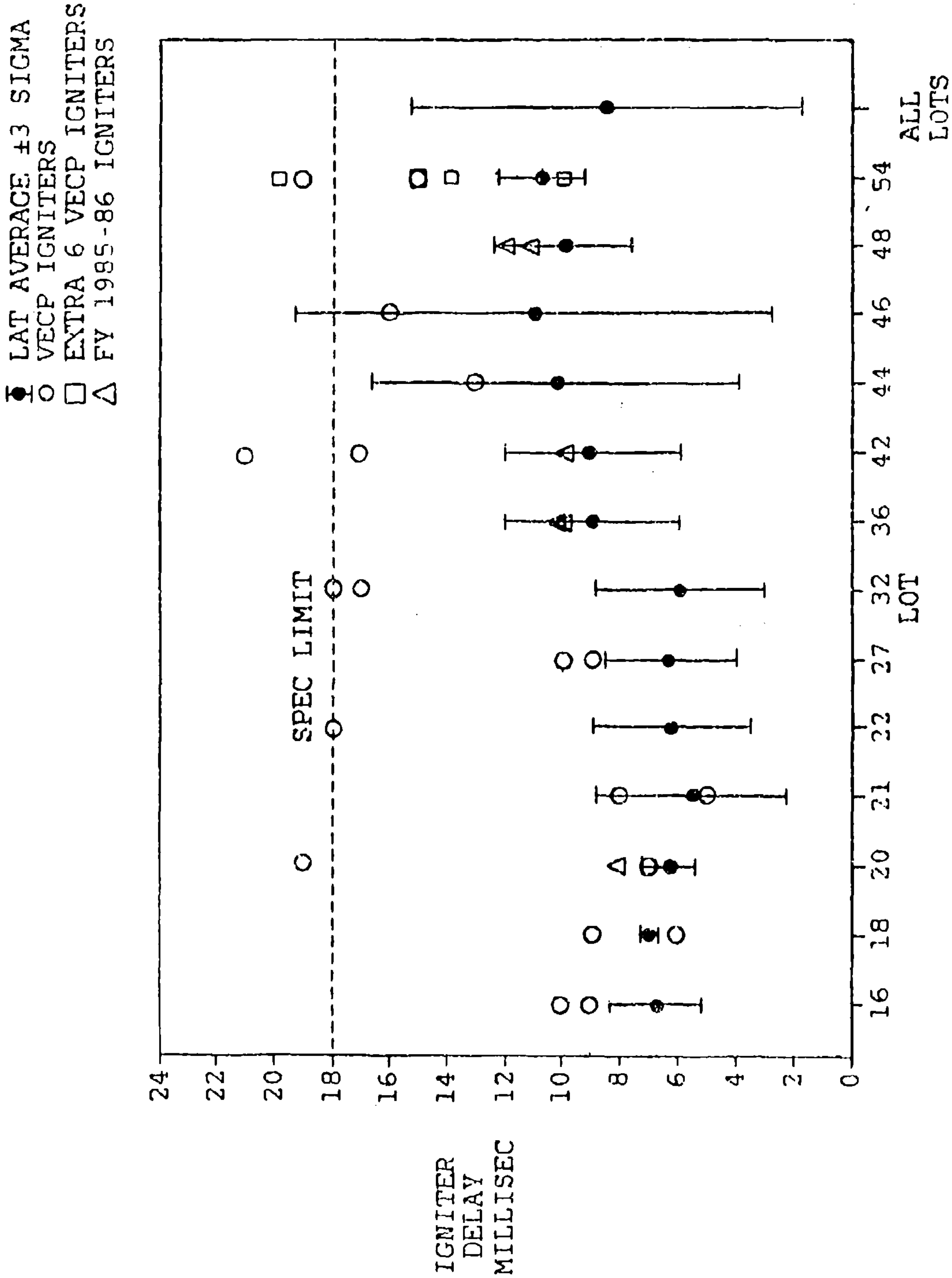


Figure 39. Igniter Delay/Lot Acceptance Comparison for VECP B-177 Igniters

PARAMETER	STUDENT t-VALUE	REGRESSION SIGNIFICANCE (α =0.05)	R^2 (%)	SLOPE	INTERCEPT	PROJECTED VALUE AT 34 YEARS	SPEC LIMIT
Delay (msec)	1.91	No	1.9	-	-	10.0	18 max
Burn Duration (seconds)	3.63	Yes	8.6	4.6e-5	.274	.295	-
Average Pressure (psia)	-1.94	No	2.6	-	-	1026	840 min 1217 max
Maximum Pressure (psia)	2.70	Yes	5.2	.176	1112	1184	1476 max
Pressure-Time Integral (psia-sec)	2.60	Yes	4.6	.026	281	291	250 min 317 max

Figure 40. Regression Analysis Results

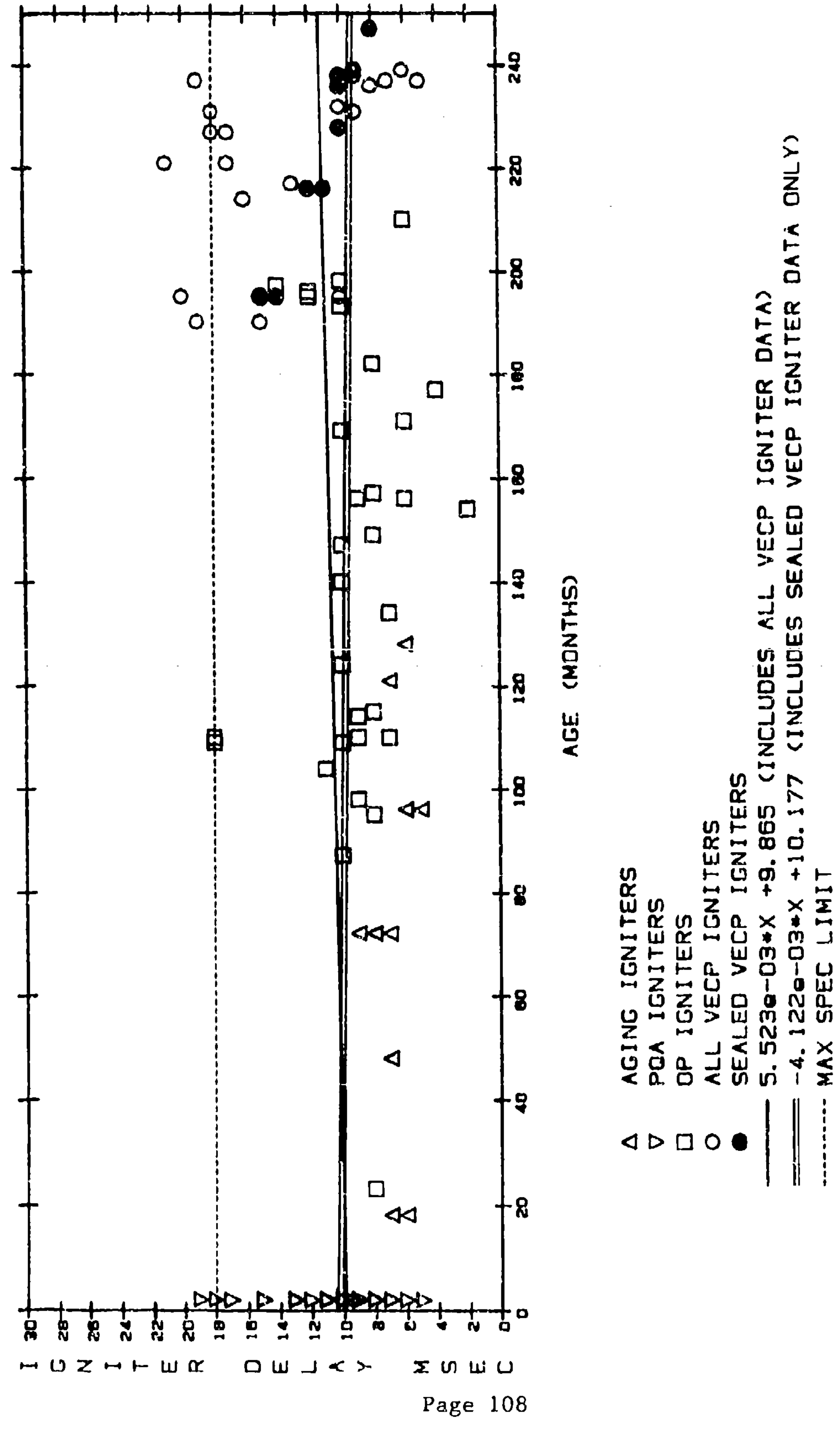


Figure 41. Ignition Delay vs Age - All Igniters Fired
(Lot Acceptance Igniters Excluded)

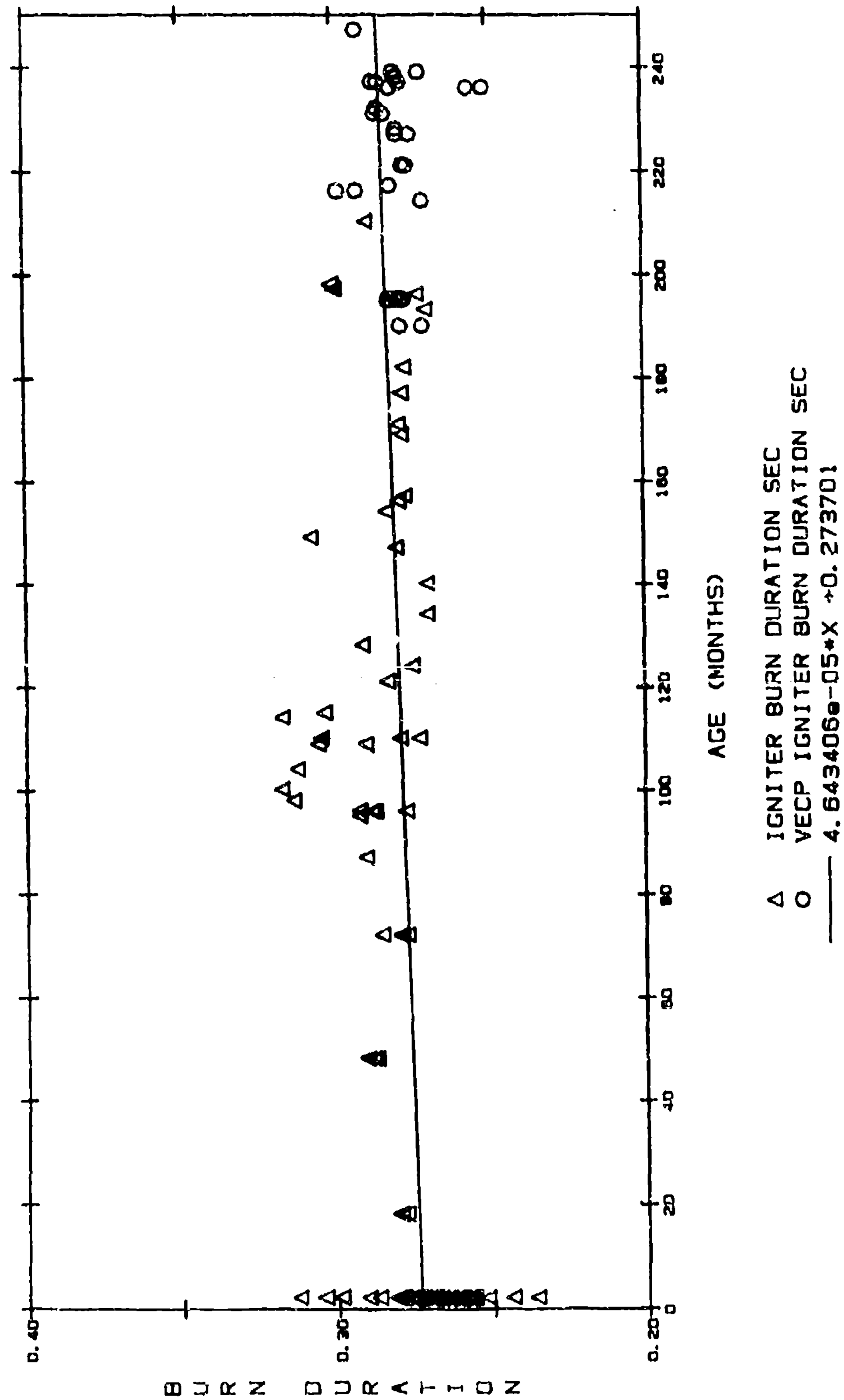


Figure 42. Igniter Burn Duration vs Age - All Igniters Fired
(Lot Acceptance Igniters Excluded)

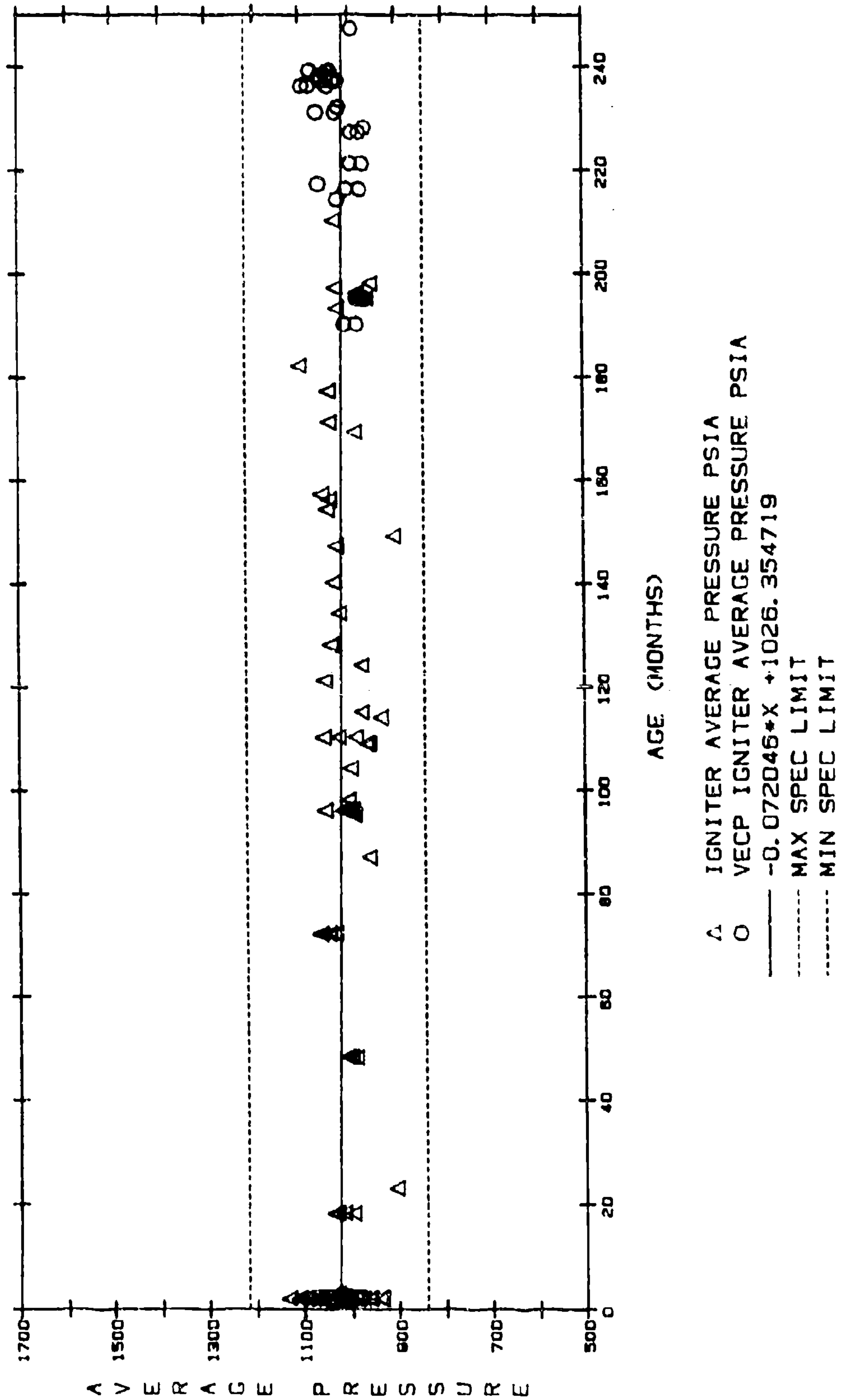


Figure 43. Igniter Average Pressure vs Age - All Igniters Fired (Lot Acceptance Igniters Excluded)

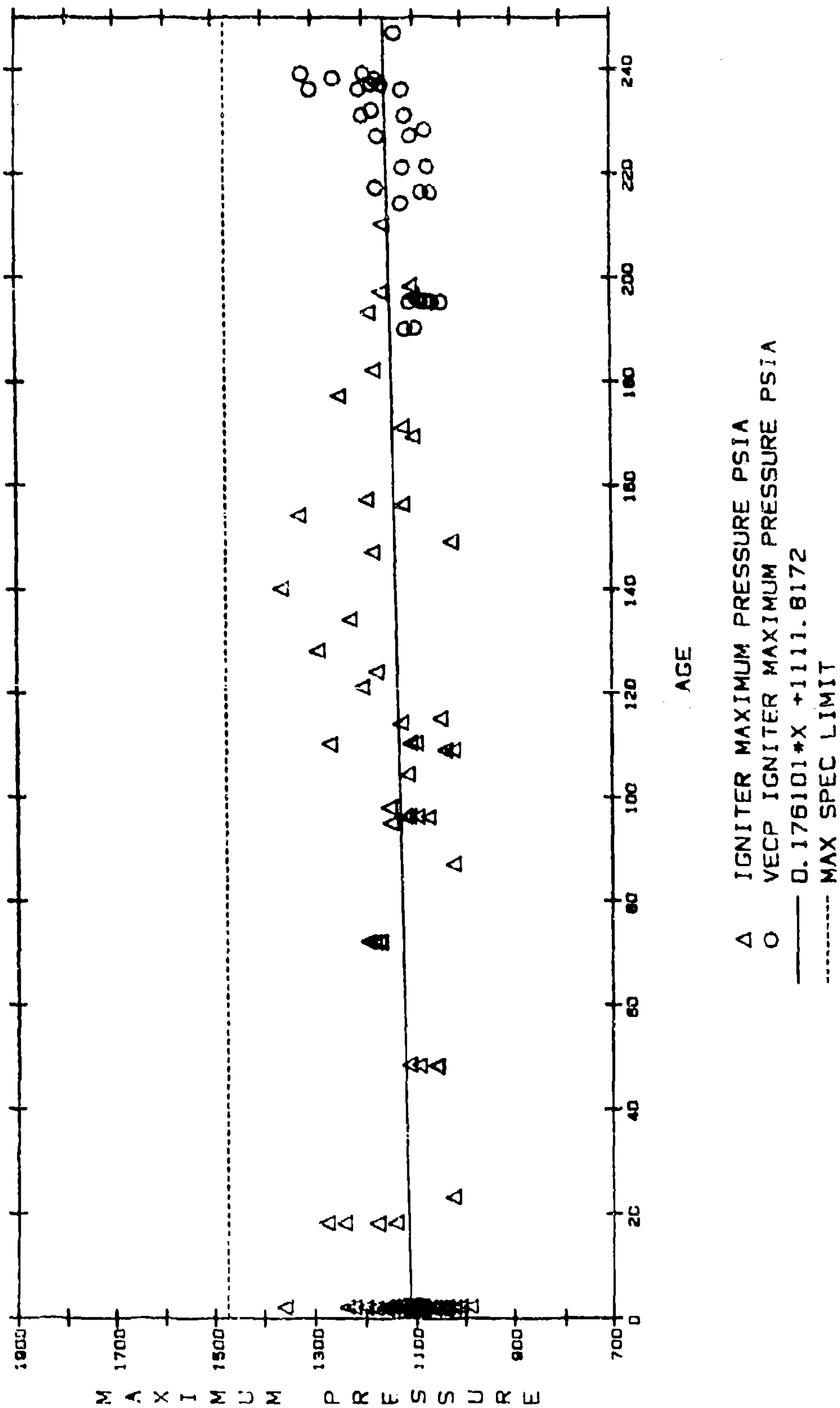


Figure 44. Igniter Maximum Pressure vs Age - All Igniters Fired (Lot Acceptance Igniters Excluded)

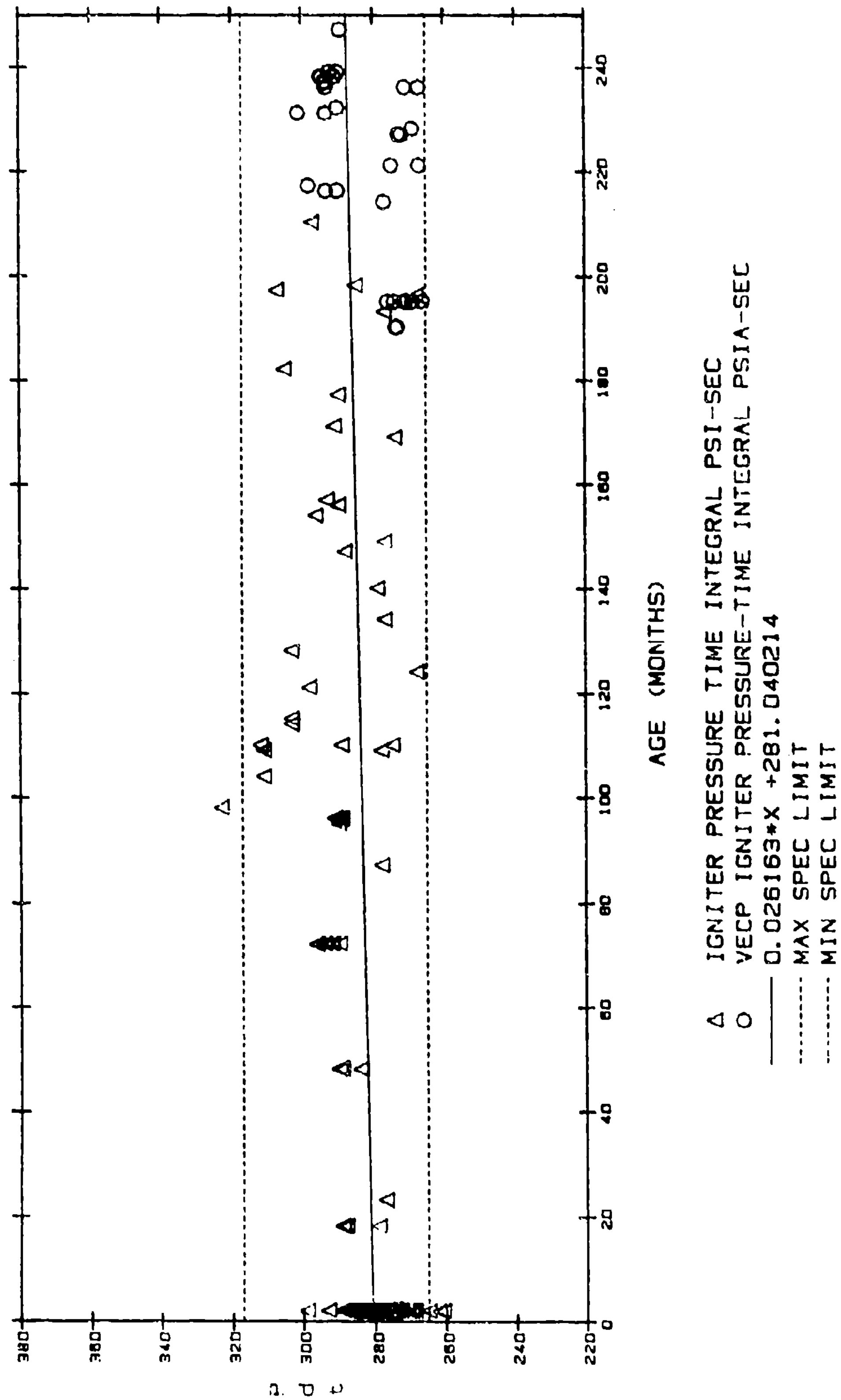


Figure 45. Igniter Pressure Time Integral vs Age - All Igniters Fired (Lot Acceptance Igniters Excluded)

	2 To 100 Months		101 To 247 Months			
	N	Standard Deviation	N	Standard Deviation	F Ratio	Significant Difference Between populations at 95% Confidence
Igniter Delay	81	2.97	54	4.39	1.48	No
Burn Duration	81	.015	54	.012	.79	No
Average Pressure	81	38.6	54	41.7	1.1	No
Maximum Pressure	75	61.1	54	78.2	1.3	No
Pressure Time Integral	81	9.3	54	13.0	1.4	No

Figure 46. Variance Analysis Results

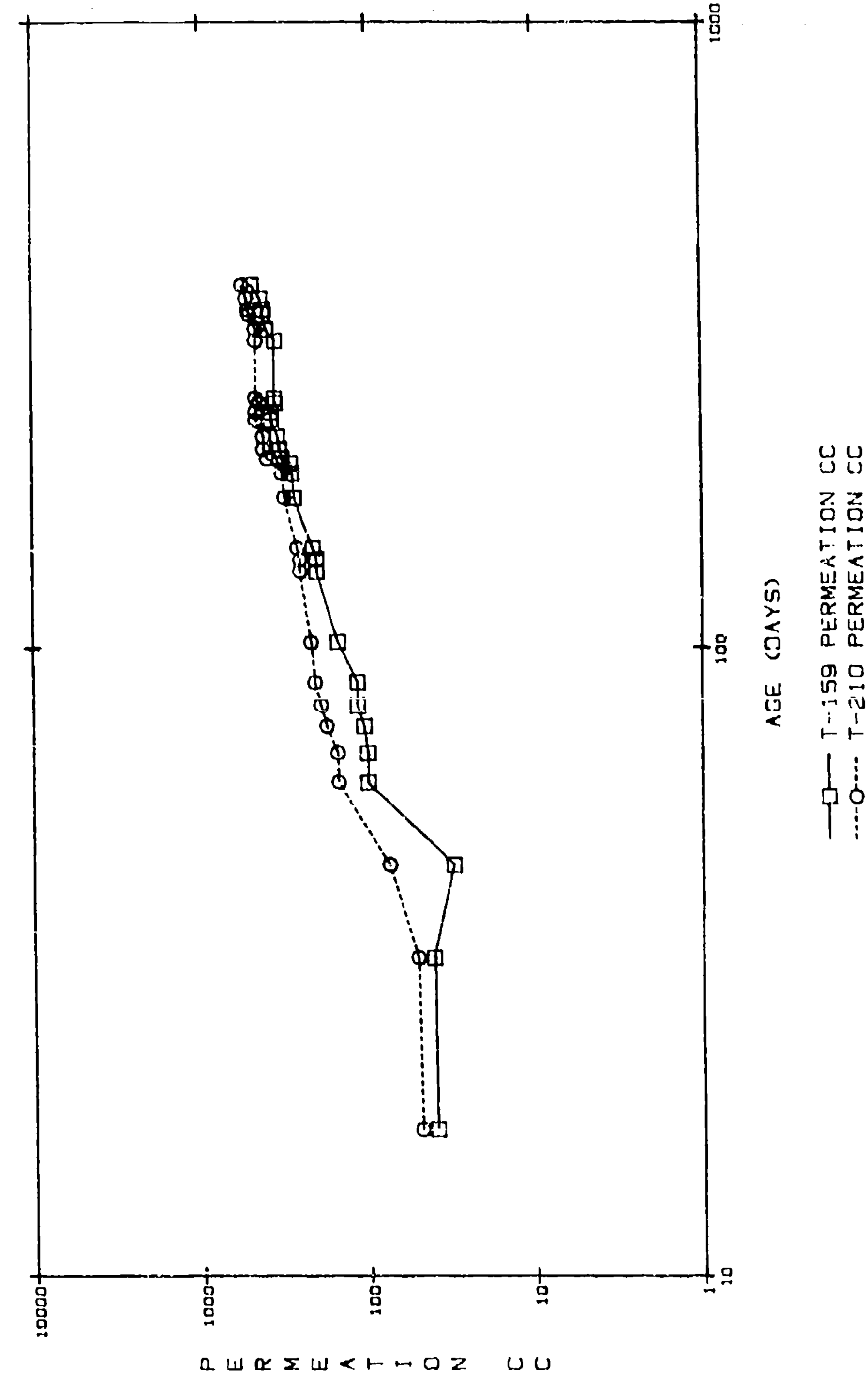


Figure 47. Bladder Freon Permeation vs Age Tanks T-159 and T-210

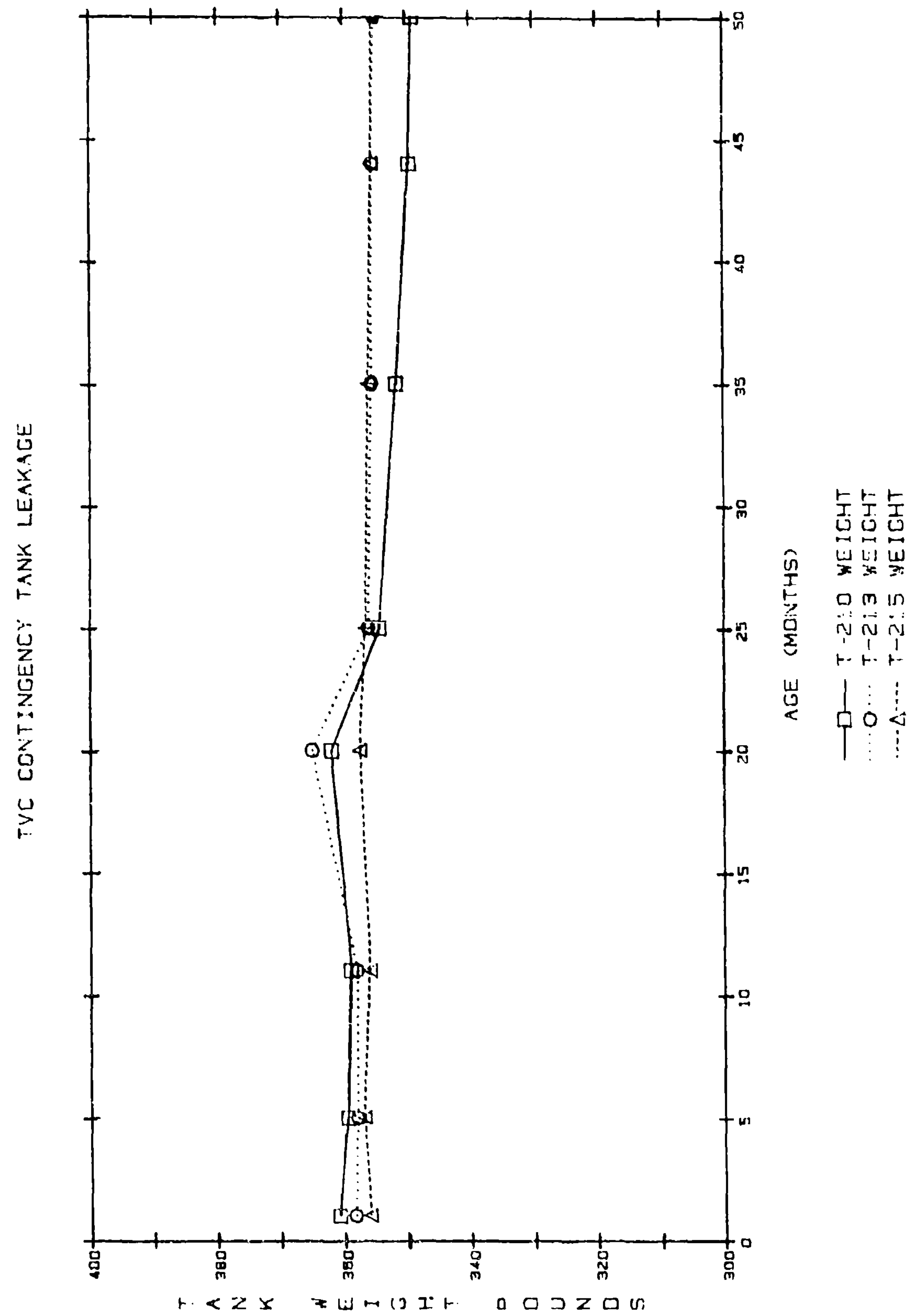
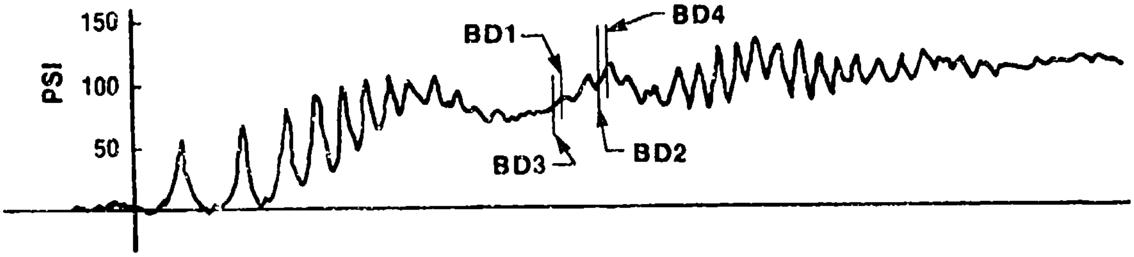
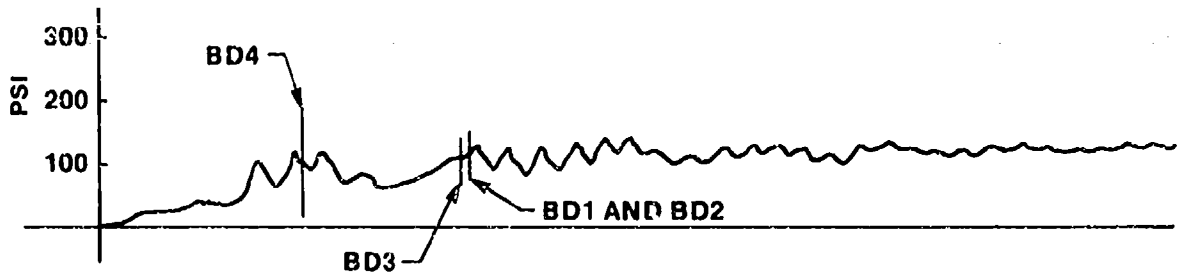


Figure 48. TVC Contingency Tank Leakage



TANK-ABB 0800 PRESSURE TIME



TANK ABB 1510 PRESSURE TRACE

Figure 49. Pressure/Time Curves for Totoidal Cold Flow Tests

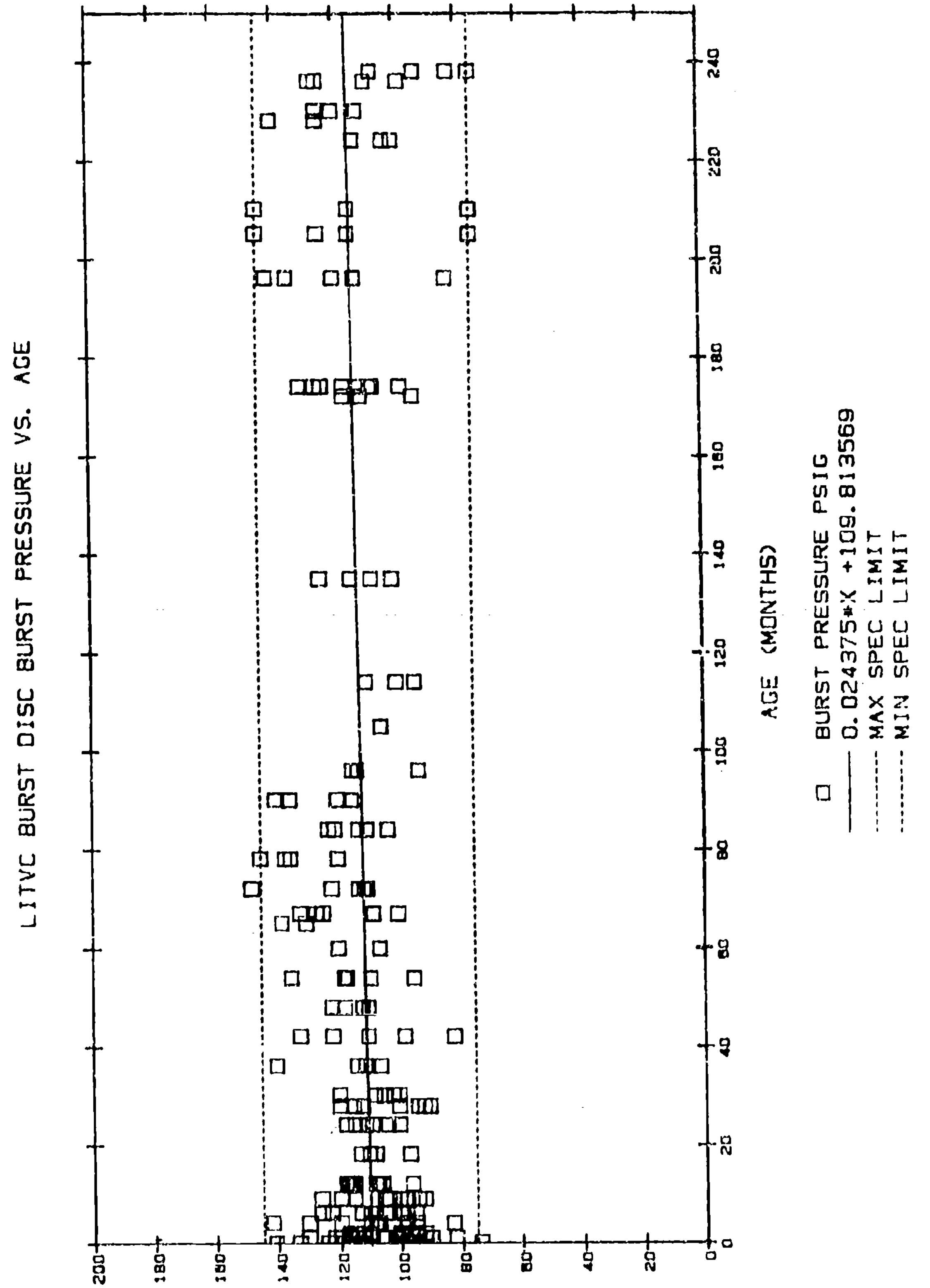


Figure 50. LITVC Burst Disc Burst Pressure vs Age

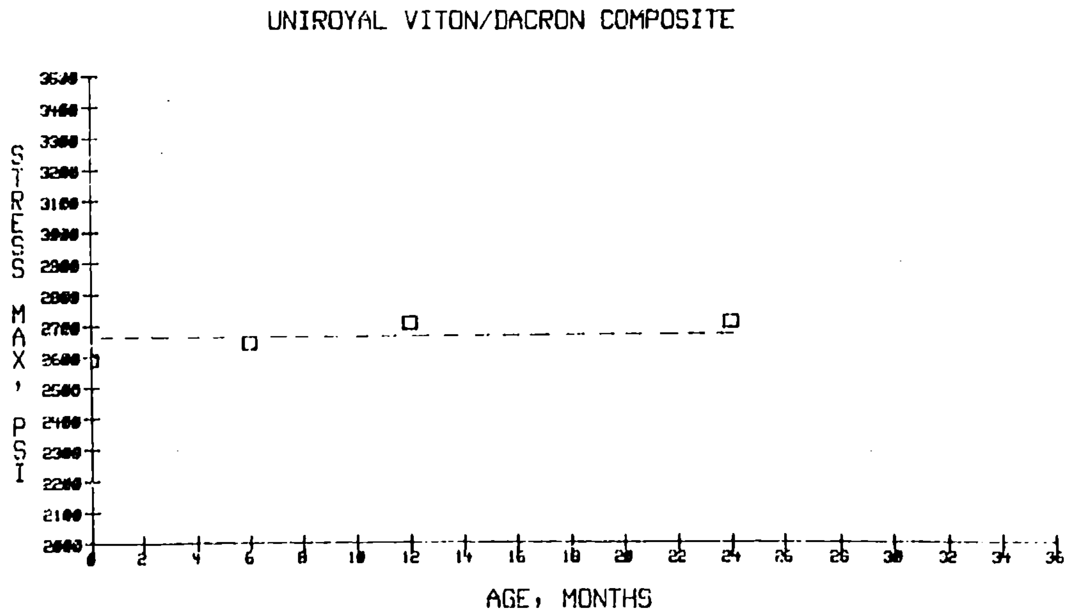


Figure 51. Uniroyal Viton/Dacron Composite

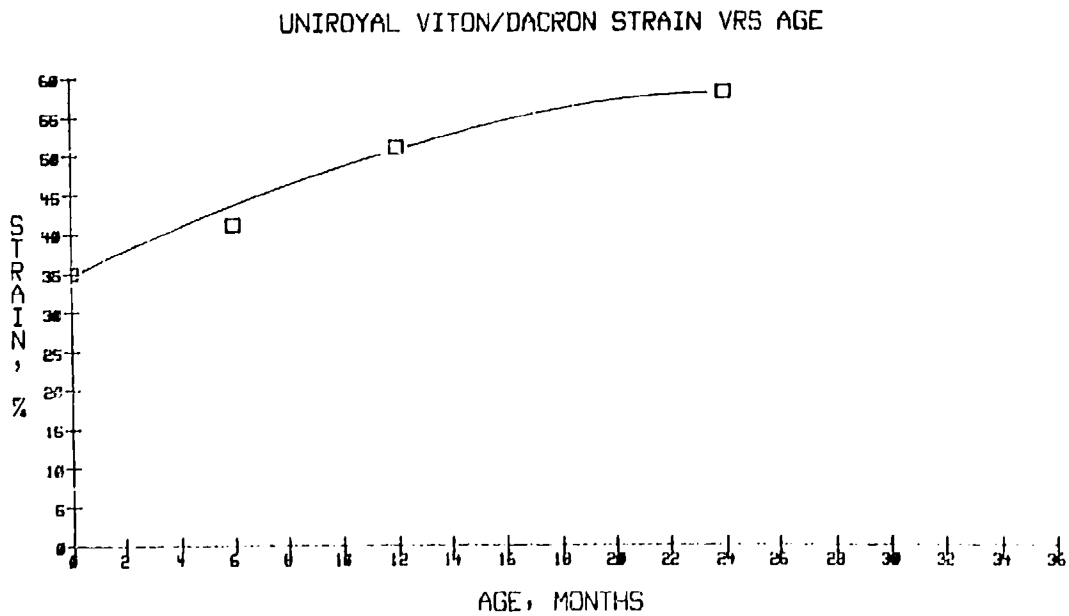


Figure 52. Uniroyal Viton/Dacron Strain vs Age

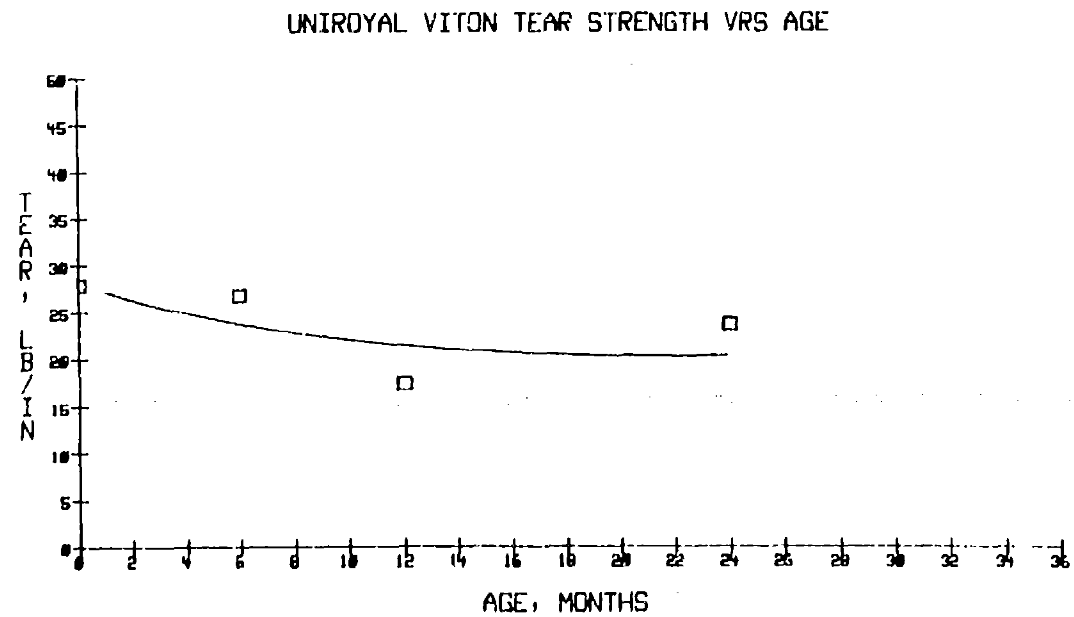


Figure 53. Uniroyal Viton Tear Strength vs Age

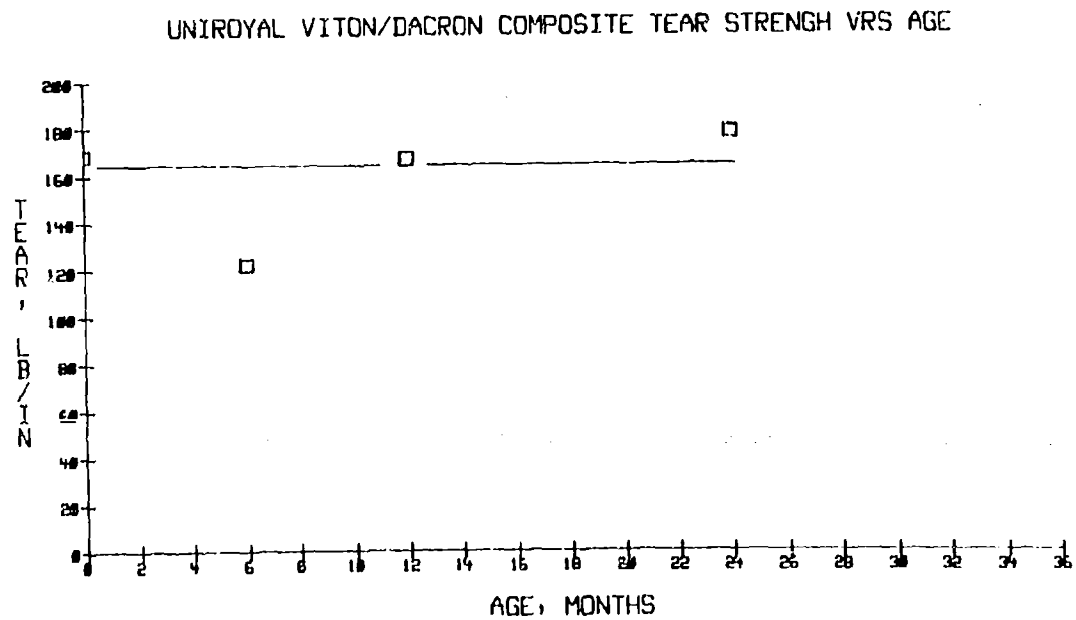


Figure 54. Uniroyal Viton/Dacron Composite Tear Strength vs Age

Appendix A

Materials From Motors

Cast Date: 10-72
Lot Combination: 52 (GTR)

PROPELLANT

	Uniaxial Tensile	Relaxation
Test Temp., °F	77	77
Crosshead Rate, in./min	1.0	0.5
Applied Strain, %	-	2.0

Distance From Bore Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	Relaxation Modulus, E_r, psi — Relaxation Time, Minutes 0.1	1.0	10.0
Surface					68			
0.1	103	22.4	28.6	868	68			
0.2	98	24.2	33.4	776	66			
0.3	100	24.0	31.2	754	67			
0.4	102	23.4	33.8	739	68			
0.5	100	24.0	30.7	746	70			
0.6	100	24.2	31.4	746	68			
0.7	102	21.8	30.8	761	69			
0.8	100	22.2	31.0	740	70			
0.9	101	21.8	32.3	782	71			
1.0	102	21.6	32.5	776	72			
1.5	110	21.6	29.4	854	70			
2.0	113	19.2	27.7	890	70			

Distance From Bond Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	0.1	1.0	10.0
Surface					64			
0.1	96	15.1	19.4	942	70	775	537	460
0.2	92	20.2	27.9	812	69	730	453	377
0.3	94	21.6	29.6	753	68	612	381	310
0.4	95	22.0	32.5	731	69	544	340	271
0.5	98	22.0	30.0	753	69	523	329	260
0.6	98	22.4	30.1	738	69	597	370	287
0.7	100	21.4	28.8	760	67	564	353	278
0.8	100	21.2	29.8	775	68	550	344	270
0.9	100	21.2	28.8	766	70	585	370	288
1.0	102	21.4	29.6	784	68	581	374	298
1.5	108	20.3	28.2	825	68	564	372	295
2.0	107	20.3	27.8	846	68	684	452	356

INSULATION

Test Temp., °F 77
Crosshead Rate in./min 1.0
Applied Strain % 2.0

	Relaxation Modulus, E_r, psi — Relaxation Time, Minutes		
	4082	3370	2950
	4497	3681	3248
$\bar{X}$	4290	3526	3099

PROPELLANT-LINER-INSULATION

Type Test	Test Temp °F	Stress σ_m psi	Time to Failure, Minutes	Type Failure, %
Mini DPT	77	24	0.086	CL (Extremely
		13	0.116	CL Sticky
		7	0.176	CL Liner)
		3	0.02	CL
	$\bar{X}$	12	0.100	

MECHANICAL PROPERTIES RESULTS FOR EXCISED
SAMPLES REMOVED FROM STAGE II MOTOR AA21051
AGED 161 MONTHS

Figure A-1. Mechanical Properties Results for Excised Samples Removed from Stage II Motor AA21051, Aged 161 Mo

Cast Date: 7-71
Lot Combination: 45 (Phillips)

PROPELLANT

Test Temp., °F	77	77
Crosshead Rate, in./min	1.0	0.5
Applied Strain, %	-	2.0

	UNIAXIAL TENSILE					RELAXATION MODULUS, E_r, psi RELAXATION TIME, MINUTES		
Distance From Bore Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	0.1	1.0	10.0
Surface					68			
0.1	127	15.5	21.0	1283	65			
0.2	129	15.3	24.4	1254	66			
0.3	131	15.4	23.0	1292	67			
0.4	130	15.2	22.7	1277	67			
0.5	129	14.8	22.2	1276	68			
0.6	128	15.0	22.9	1277	68			
0.7	128	15.4	23.1	1283	66			
0.8	127	15.3	22.9	1255	65			
0.9	128	15.5	24.4	1255	65			
1.0	127	15.7	24.6	1270	68			
1.5	123	17.4	25.1	1131	66			
2.0	115	20.1	30.9	949	65			
Distance From Bond Surface, in.								
Surface					59			
0.1	86	21.2	28.3	688	66	436	261	200
0.2	108	17.7	26.1	1007	70	801	466	350
0.3	116	16.8	24.2	1087	70	955	564	425
0.4	117	16.6	24.9	1066	68	892	536	402
0.5	120	16.8	22.9	1094	69	1069	646	495
0.6	119	17.0	22.2	1138	70	934	558	420
0.7	115	16.6	25.5	1089	69	975	600	455
0.8	118	16.6	24.6	1081	69	980	594	442
0.9	118	16.6	24.8	1118	69	1022	613	451
1.0	117	16.8	24.4	1081	67	1045	625	470
1.5	101	20.3	35.3	826	66	770	435	316
2.0	97	23.6	38.3	725	66	691	380	279

INSULATION

Test Temp., °F	77
Crosshead Rate in./min	1.0
Applied Strain %	2.0

	RELAXATION MODULUS, E_r, psi RELAXATION TIME, MINUTES		
	3934	3231	2846
	3921	3243	2893
X	3928	3237	2870

PROPELLANT-LINER-INSULATION

Type Test	Test Temp °F		Stress σ_m psi	Time to Failure, Minutes	Type Failure, %
Mini DPT	77		23	0.033	100 CLI
			24	0.031	100 CLI
			16	0.046	100 CLI (Sticky liner)
		X	21	0.037	

MECHANICAL PROPERTIES RESULTS FOR EXCISED
SAMPLES REMOVED FROM STAGE II MOTOR AA20887
AGED 170 MONTHS

Figure A-2. Mechanical Properties Results for Excised Samples Removed from Stage II Motor AA20887, Aged 170 Mo

Cast Date: 5-76
Lot Combination: 67 (Phillips)

PROPELLANT		
Test Temp., °F	77	77
Crosshead Rate, in./min	1.0	0.5
Applied Strain, %	-	2.0

	UNIAXIAL TENSILE					RELAXATION MODULUS, E_r, psi RELAXATION TIME, MINUTES		
Distance From Bore Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	0.1	1.0	10.0
Surface					75			
0.1	156	13.8	15.3	1628	73			
0.2	155	15.9	21.0	1447	73			
0.3	154	15.1	20.4	1466	72			
0.4	152	15.5	20.3	1423	74			
0.5	152	15.5	21.0	1408	72			
0.6	151	15.7	20.8	1400	75			
0.7	148	15.3	20.1	1393	71			
0.8	147	15.5	21.8	1349	72			
0.9	145	15.5	20.7	1356	72			
1.0	145	15.2	20.8	1400	72			
1.5	115	21.2	33.4	842	71			
2.0	116	20.8	33.6	872	68			
Distance From Bond Surface, in.								
Surface					63			
0.1	114	10.7	12.0	1378	72	1528	1078	867
0.2	140	15.3	20.5	1336	72	1400	940	738
0.3	141	15.3	20.3	1328	72	1375	952	762
0.4	140	15.1	19.4	1350	72	1426	985	786
0.5	143	15.1	20.0	1378	70	1454	1010	802
0.6	143	15.3	20.0	1356	69	1409	978	782
0.7	141	15.5	20.8	1356	71	1420	986	784
0.8	142	15.5	21.0	1356	71	1413	978	780
0.9	143	15.1	20.6	1363	75	1321	923	744
1.0	142	15.3	20.6	1326	73	1388	953	761
1.5	110	23.3	36.5	750	72	720	444	344
2.0	111	22.0	36.0	777	72	726	456	348

INSULATION	
Test Temp., °F	77
Crosshead Rate in./min	1.0
Applied Strain %	2.0

	RELAXATION MODULUS, E_r, psi RELAXATION TIME, MINUTES		
	3429	2675	2277
	3208	2510	2160
X	3318	2592	2218

PROPELLANT-LINER-INSULATION

Type Test	Test Temp °F		Stress σ_m psi	Time to Failure, Minutes	Type Failure, %
Mini DPT	77		45	0.40	90 APL/10 CL
			54	0.56	95 APL/ 5 CL
			33	0.37	10 APL/30 CL/60 ALI
		X	44	0.44	

MECHANICAL PROPERTIES RESULTS FOR EXCISED
SAMPLES REMOVED FROM STAGE II MOTOR AA21480
(PLUG MOTOR 1976), AGED 110 MONTHS

Figure A-3. Mechanical Properties Results for Excised Samples Removed from Stage II Motor AA21480, Aged 110 mo

Cast Date: 9-75
Lot Combination: 64 (Phillips)

PROPELLANT

Test Temp., °F	77	77
Crosshead Rate, in./min	1.0	0.5
Applied Strain, %	-	2.0

Distance From Bore Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	Relaxation Modulus, E_r, psi — Relaxation Time, Minutes 0.1	1.0	10.0
Surface					77			
0.1	128	15.6	22.9	1265	72			
0.2	131	16.2	25.0	1218	75			
0.3	134	16.0	23.5	1265	73			
0.4	132	15.8	23.0	1235	75			
0.5	134	15.4	22.9	1279	77			
0.6	132	15.4	20.8	1265	76			
0.7	128	15.6	22.2	1235	76			
0.8	126	15.8	22.5	1163	75			
0.9	128	15.9	23.8	1177	76			
1.0	125	15.8	23.2	1190	75			
1.5	118	17.4	27.2	1044	72			
2.0	96	21.6	37.4	705	65			

Distance From Bond Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	0.1	1.0	10.0
Surface					66			
0.1	104	17.0	23.0	910	75	790	518	404
0.2	124	14.8	21.7	1234	75	1381	896	688
0.3	122	15.2	22.4	1160	77	1300	854	674
0.4	124	15.8	22.7	1154	76	1278	839	656
0.5	126	15.5	21.4	1168	73	1339	882	688
0.6	126	16.7	23.6	1132	75	1299	857	677
0.7	123	16.6	24.2	1094	75	1079	709	560
0.8	124	16.5	23.8	1132	76	1330	864	682
0.9	124	17.0	23.6	1102	76	1335	892	710
1.0	124	15.9	23.4	1108	74	1170	789	638
1.5	100	21.2	34.0	720	72	910	558	433
2.0	96	22.0	36.0	646	66	686	420	322

INSULATION

Test Temp., °F	77
Crosshead Rate in./min	1.0
Applied Strain %	2.0

RELAXATION MODULUS, E_r, psi
RELAXATION TIME, MINUTES

	3552	2803	2332
	3137	2612	2204
X	3344	2708	2268

PROPELLANT-LINER-INSULATION

Type Test	Test Temp °F		Stress σ_m psi	Time to Failure, Minutes	Type Failure, %
Mini DPT	77		24	0.037	CL (Extremely
			19	0.037	CL Sticky
			21	0.048	CL Liner)
		X	21	0.041	

MECHANICAL PROPERTIES RESULTS FOR EXCISED
SAMPLES REMOVED FROM STAGE II MOTOR AA21434
AGED 122 MONTHS

Figure A-4. Mechanical Properties Results for Excised Samples Removed from Stage II Motor AA21434, Aged 122 Mo

Cast Date: 9-83
Lot Combination: 84B (Phillips)

PROPELLANT

Test Temp., °F	77	77
Crosshead Rate, in./min	1.0	0.5
Applied Strain, %	-	2.0

Distance From Bore Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	Relaxation Modulus, E_r, psi — Relaxation Time, Minutes 0.1	1.0	10.0
	UNIAXIAL TENSILE							
Surface					72			
0.1	152	12.4	14.4	1771	72			
0.2	140	15.2	21.1	1364	72			
0.3	140	15.0	20.3	1393	70			
0.4	140	14.4	19.1	1401	71			
0.5	140	14.8	20.3	1379	74			
0.6	139	14.4	19.0	1386	72			
0.7	137	14.6	19.0	1366	72			
0.8	138	14.2	18.9	1387	70			
0.9	139	14.6	20.2	1401	70			
1.0	135	15.2	20.9	1284	72			
1.5	128	16.6	22.9	1117	67			
2.0	129	16.4	22.4	1147	68			

Distance From Bond Surface, in.	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	0.1	1.0	10.0
Surface					71			
0.1	128	11.8	13.1	1416	73	1183	840	668
0.2	139	13.1	17.3	1540	71	1437	940	718
0.3	141	13.5	17.5	1512	71	1448	952	734
0.4	143	14.0	17.7	1475	71	1343	887	688
0.5	143	14.4	18.7	1445	72	1318	872	676
0.6	141	14.8	19.0	1329	71	1224	807	627
0.7	142	15.1	19.4	1351	72	1328	880	684
0.8	140	15.3	20.2	1293	71	1057	704	549
0.9	134	16.6	22.4	1162	71	988	644	486
1.0	132	16.6	23.1	1125	71	1010	644	476
1.5	127	17.4	23.8	1053	68	1153	732	560
2.0	126	17.4	24.2	1045	68	1134	725	571

INSULATION

Test Temp., °F	77
Crosshead Rate in./min	1.0
Applied Strain %	2.0

RELAXATION MODULUS, E_r, psi
RELAXATION TIME, MINUTES

	2309	1845	1507
	2225	1704	1478
X	2268	1774	1492

PROPELLANT-LINER-INSULATION

Type Test	Test Temp °F		Stress σ_m psi	Time to Failure, Minutes	Type Failure, %
Mini DPT	77		62	0.21	APL
			78	0.22	APL
			55	0.16	APL
		X	65	0.20	

MECHANICAL PROPERTIES RESULTS FOR EXCISED
SAMPLES REMOVED FROM STAGE II MOTOR MSEX-II
(PLUG MOTOR 1984A), AGED 24 MONTHS

Figure A-5. Mechanical Properties Results for Excised Samples Removed from Stage II Motor MXEX-II (Plug Motor 1984A), Aged 24 Mo

MOTOR NO.	AGE MOS.	CTPB	DENSITY	SWELLING RATIO	GEL FILLER FRACTION	% H2O	% DOP	SHORE A	SWELLING RATIO	GEL FILLER FRACTION
20011	198.0	GTR	1.230	1.670	0.909	2.06	1.20	73	2.400	0.280
20013	125.0	GTR				2.05		76	2.150	
20026	206.0	GTR	1.219	1.680	0.896	2.06		73		0.150
20028	156.0	GTR				1.84		73		0.326
20029	123.0	GTR				1.92			2.050	
20033	203.0	GTR		1.700		1.96	1.30	67		0.211
20035	123.0	GTR				2.06		71	2.050	
20041	148.0	GTR		1.728	0.889			73	2.360	0.323
20042	142.0	GTR	1.230			1.89		63	2.350	
20043	209.0	GTR	1.228	1.660	0.891	2.12	1.20			0.393
20045	197.0	GTR		1.710	0.895	2.18	1.30	72		0.104
20047		GTR		1.726	0.891	1.85		70	2.310	0.448
20051	192.0	GTR		1.680	0.904	1.86	1.20		2.220	0.468
20053	186.0	GTR	1.231	1.660	0.898	1.95	1.21	74		0.385
20071	123.0	GTR				1.92		64	2.200	
20074	210.0	GTR	1.217	1.710	0.902	2.04	1.20	79		0.304
20077	181.0	GTR	1.232	1.670	0.899	1.62	1.21			0.257
20080	154.0	GTR				1.92		75		
20083	181.0	GTR	1.231	1.700	0.892	1.89	1.13		2.500	0.237
20086	181.0	GTR	1.228	1.720	0.892	1.98	1.28	73		0.139
20094	177.0	PHIL	1.229	1.670	0.892	1.82	1.60	69		0.375
20095	199.0	PHIL								
20097	122.0	PHIL				1.91		70	2.120	
20098	169.0	PHIL	1.158	1.670	0.890	1.95				
20099	175.0	PHIL	1.230	1.710	0.881	2.03	0.90		2.280	0.351
20100	181.0	PHIL	1.226	1.700	0.888	1.82	1.40	67		0.410
20101	216.0	PHIL			0.895		1.16		1.920	0.418
20103	138.0	PHIL				1.70		70	2.220	
20104	177.0	PHIL		1.710	0.907	2.01	0.60			0.235
20106	222.0	PHIL			0.896		1.50			0.160
20107	182.0	PHIL	1.233	1.680	0.907	2.23	1.10	68		0.429
20108	165.0	PHIL		1.707	0.883	1.90			2.372	0.488
20110	156.0	PHIL				1.90			2.370	0.364
20114	122.0	GTR				1.83		69	2.100	
20114	221.0	GTR			0.896		1.60			0.185
20118	116.0	GTR				2.10			2.110	
20125	181.0	GTR	1.235	1.690	0.899	1.97	1.50	74		0.413
20143	120.0	PHIL				1.87		68	2.050	
20143	216.0	PHIL			0.896		1.00		2.300	0.312
20144	191.0	GTR	1.230	1.740	0.891	2.00	1.30	79	2.360	0.332

Figure A-6. Properties of M/M Excised Samples (Original Production), Sheet 1 of 3

MOTOR NO.	AGE MOS.	CTPB	DENSITY	SWELLING RATIO	GEL FILLER FRACTION	% H2O	% DOP	SHORE A	SWELLING RATIO	GEL FILLER FRACTION
20147	121.0	PHIL				1.91			2.280	
20161	114.0	PHIL				2.05			2.120	
20167	183.0	PHIL	1.223	1.680	0.890	2.06	1.20	67	2.390	0.299
20182	156.0	PHIL		1.674	0.887	2.03			2.500	0.231
20184	137.0	GTR				1.84		75	2.340	
20189	116.0	GTR				1.88		70	2.000	
20192	137.0	GTR				1.82		73	2.130	
20204	112.0	GTR				2.04		72	2.020	
20209	114.0	PHIL				1.74			2.010	
20224	176.0	GTR							2.500	0.232
20226	178.0	PHIL	1.228	1.630	0.893	2.00	1.10		2.010	0.334
20261	171.0	PHIL	1.225	1.690	0.887	2.01	1.60			0.268
20263	176.0	PHIL	1.227	1.660	0.899	1.85	1.30	73	2.340	0.318
20267	115.0	PHIL				1.92			2.000	
20275	114.0	PHIL				1.85			2.000	
20288	176.0	PHIL	1.224	1.670	0.880	1.91		74	2.360	0.264
20295	106.0	GTR				1.98		75	2.180	
20301	190.0	PHIL	1.240	1.690	0.905		1.10	74		0.036
20330	112.0	PHIL				1.77			2.020	
20332	110.0	GTR				1.92		68	2.050	
20355	109.0	GTR				1.95		65	2.020	
20369	197.0	GTR			0.907		1.40			0.073
20369	108.0	GTR				1.92		72	2.130	
20402	216.0	GTR			0.897		1.60		2.040	0.273
20415	180.0	GTR		1.710	0.883		1.30	71		0.276
20419	203.0	GTR			0.900		1.10			0.252
20424	105.0	GTR				2.06		69	1.910	
20436	189.0	GTR	1.230	1.660	0.886	2.37	1.40	67		0.346
20442	106.0	GTR				1.84			2.050	
20442	192.0	GTR			0.902		1.20		1.990	0.329
20472	103.0	GTR				1.75			1.900	
20473	195.0	GTR			0.903		1.20		2.270	0.358
20479	167.0	GTR	1.236	1.670	0.895	2.07	1.60			0.325
20488	192.0	GTR			0.894		1.40		2.120	0.449
20493	100.0	GTR				1.73		65	1.990	
20493	200.0	GTR			0.898		1.40		2.300	0.341
20508	98.0	PHIL				1.78		65	1.850	
20515	97.0	GTR				1.72		68	1.980	
20530	203.0	GTR			0.898		1.20		1.990	0.428
20554	91.0	GTR				1.73		63	2.080	

Figure A-6. Properties of M/M Excised Samples (Original Production), Sheet 2 of 3

MOTOR NO.	AGE MOS.	CTPB	DENSITY	SWELLING RATIO	GEL FILLER FRACTION	% H2O	% DOP	SHORE A	SWELLING RATIO	GEL FILLER FRACTION
20559	90.0	GTR				1.90		68	1.840	
20559	181.0	GTR			0.894		1.20		2.100	0.453
20567	89.0	GTR				1.96		71	1.940	
20579	88.0	GTR				1.70		59	1.990	
20579	167.0	GTR	1.243	1.600	0.895		1.30	68		0.330
20587	83.0	PHIL				2.11		67	2.230	
20596	192.0	GTR			0.893		1.40		2.110	0.402
20598	83.0	PHIL				1.80		64	1.940	
20613	194.0	PHIL			0.899		1.10		2.100	0.361
20615	160.0	GTR	1.237	1.690	0.888	2.02	1.50	75		0.444
20616	84.0	GTR				1.77		68	1.950	
20621	84.0	GTR				1.93		65	1.880	
20629	196.0	PHIL			0.885		1.40		2.440	0.270
20637	164.0	GTR						63		
20672	79.0	GTR				1.80		66	1.850	
20715	73.0	PHIL				1.86		63	1.920	
20726	71.0	GTR				1.74		59	1.950	
20745	68.0	GTR				1.92		65	1.860	
20759	67.0	PHIL				1.81		52	1.850	
20785	64.0	GTR				1.75		62	1.890	
20788	64.0	GTR				1.85		61	1.870	
20846	57.0	PHIL				1.87		54	1.790	
20863	57.0	GTR				1.73		57	1.930	
20887	170.0	.			0.889		0.93			0.260
20888	54.0	PHIL				1.77		68	1.840	
20925	51.0	PHIL				1.65		62	1.850	
20971	47.0	GTR				1.84		65	1.810	
20987	44.0	GTR				1.96		74	1.840	
21049	138.0	GTR			0.889		1.50		2.340	0.234
21051	161.0				0.907		1.68			0.130
21321	138.0	GTR		1.640	0.891	1.77	1.59	74		0.036
21434	122.0				0.881		1.60		2.280	0.273
21480	108.0	P		1.640	0.890	1.77	1.67		1.890	0.454
MS-4	142.0	PHIL				1.90		64	2.210	
MSEX-2	24.0	PHIL			0.856	1.94	3.40	71	1.890	0.613
MSEX-2	2.5	PHIL		1.730	0.848	1.88	5.97		1.880	0.703
QT-11	126.0	GTR				1.86				
QT-SP2	130.0	GTR				2.18			2.140	

Figure A-6. Properties of M/M Excised Samples (Original Production), Sheet 3 of 3

Motor Characteristics	Visual Inspection Ranking Criteria		
Main Criteria	Very Poor	Poor	Fair
Forward Nipple Gap	$\geq$ 0.06	$\geq$ 0.03	$\leq$ 0.03
Lifting	$\geq$ 0.04	$\geq$ 0.03	$\leq$ 0.03
Aft Nipple Gap	$\geq$ 0.10	$\geq$ 0.05	$\leq$ 0.05
Lifting	$\geq$ 0.10	$\geq$ 0.03	$\leq$ 0.03
Nipple Bonding	Unbounded 180° to 270° in length	45° to 90° in Length	None
Liner Quality	Sticky	Very Slightly Sticky or Slightly Sticky	Very Slightly Sticky or Normal
Cracks	Any Observed	None	None
Secondary Criteria			
Slump	> 0.25 in.	0.25 in.	$\leq$ 0.25 in.
Voids			
Quantity	> 20	10 to 20	< 10
Size	> 0.3 in.	0.1 to 0.3 in.	0.1 to 0.2 in.
Ammonium Perchlorate	Heavy to Medium	Light to Medium	None to Light
Shore "A" Hardness	$\leq$55 or $\geq$78	$\leq$63 or $\geq$73	63 to 73
Discoloration	Dark Gray/Red	Dark Gray/Red	None
Other Criteria (Tertiary)			
Rough Propellant Surface	Very Rough	Somewhat Rough	Normal
SD 844 Running on Propellant Grain	Any Observed	Any Observed	None

These criteria are not to be taken as absolute factors for determining motor condition. In general, if a motor meets 75% of the values in any one column, that column is its classification. Additionally, the table is weighted such that primary consideration is given to the main criteria. Secondary and tertiary criteria are used primarily when motors are borderline in category.

Figure A-7. Visual Inspection Ranking Criteria

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
LOT COMBO: 29. CTPB MFGR: GTR														
AA	20555.	208.00	0.040	0.000	VSS	N	0.150	0.050	SS	10.	HEAVY	REDDISH	68.10	POOR
AA	20593.	204.00	0.030	0.000	VSS	NO	0.100	0.000	VSS	10.	MEDIUM	NORM	61.40	POOR
# MOTORS IN LOT COMBO: 2			AVG AGE,MO: 206.00					LC AVG SHORE A: 64.75			3 SIGMA-SHORE A: 14.21			
LOT COMBO: 30. CTPB MFGR: PHILLIPS														
AA	20598.	204.00	0.000	0.000	VSS	NO	0.000	0.000	SS		LIGHT	RED-BROWN	76.10	FAIR
AA	20602.	208.00	0.000	0.000	VSS	0	0.100	0.050	SS	5.	HEAVY	SLIGHT BROWN	77.60	POOR
AA	20614.	207.00	0.040	0.000	STCKY	180	0.000	0.000	VSS	5.	MEDIUM	BROWN	73.20	POOR
# MOTORS IN LOT COMBO: 3			AVG AGE,MO: 206.33					LC AVG SHORE A: 75.63			3 SIGMA-SHORE A: 6.71			
LOT COMBO: 31. CTPB MFGR: GTR														
AA	20612.	207.00	0.050	0.000	STCKY	180	0.200	0.200	STCKY	2.	MEDIUM	NORM	62.30	VPOOR
# MOTORS IN LOT COMBO: 1			AVG AGE,MO: 207.00					LC AVG SHORE A: 62.30			3 SIGMA-SHORE A:			
LOT COMBO: 32. CTPB MFGR: PHILLIPS														
AA	20630.	204.00	0.020	0.000	VSS	0	0.050	0.000	VSS	5.	HEAVY	BROWN STREAKS	75.00	FAIR
AA	20645.	199.00	0.040	0.000	STCKY	NO	0.100	0.050	SS		LIGHT	NORM	74.20	POOR
# MOTORS IN LOT COMBO: 2			AVG AGE,MO: 201.50					LC AVG SHORE A: 74.60			3 SIGMA-SHORE A: 1.70			
LOT COMBO: 34. CTPB MFGR: GTR														
AA	20687.	196.00	0.000	0.000	VSS	0	0.000	0.000	VSS	24.	MEDIUM	SLIGHT RED	67.20	FAIR
# MOTORS IN LOT COMBO: 1			AVG AGE,MO: 196.00					LC AVG SHORE A: 67.20			3 SIGMA-SHORE A:			
LOT COMBO: 37. CTPB MFGR: GTR														
AA	20750.	186.00	0.030	0.000	VSS	YES	0.000	0.000	VSS	7.	MEDIUM	REDDISH	69.10	FAIR
# MOTORS IN LOT COMBO: 1			AVG AGE,MO: 186.00					LC AVG SHORE A: 69.10			3 SIGMA-SHORE A:			
LOT COMBO: 38. CTPB MFGR: GTR														

Figure A-8. SAAS-36 Visual Inspection Report August 30, 1985 to March 30, 1986, Sheet 1 of 3

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20786.	185.00	0.030	0.000	VSS	-	0.000	0.000	VSS	10.	MEDIUM	REDDISH	78.50	POOR
	# MOTORS IN LOT COMBO:		1		AVG AGE,MO:	185.00		LC AVG SHORE A:	78.50		3 SIGMA-SHORE A:			
	LOT COMBO: 39.		CTPB MFGR: PHILLIPS											
AA	20760.	185.00	0.000	0.000	VSS	NO	0.100	0.000	SS	1.	HEAVY	RED-BROWN	74.60	FAIR
	# MOTORS IN LOT COMBO:		1		AVG AGE,MO:	185.00		LC AVG SHORE A:	74.60		3 SIGMA-SHORE A:			
	LOT COMBO: 41.		CTPB MFGR: PHILLIPS											
AA	20801.	184.00	0.000	0.000	VSS	0	0.000	0.000	VSS	5.	MEDIUM	NORM	82.90	FAIR
AA	20810.	184.00	0.000	0.000	SS	0	0.150	0.000	SS	1.	LIGHT	NORM	74.30	POOR
	# MOTORS IN LOT COMBO:		2		AVG AGE,MO:	184.00		LC AVG SHORE A:	78.60		3 SIGMA-SHORE A:	18.24		
	LOT COMBO: 43.		CTPB MFGR: PHILLIPS											
AA	20818.	181.00	0.030	0.030	STCKY	270	0.100	0.050	SS		MEDIUM	REDDISH-BROWN	70.40	VPOOR
	# MOTORS IN LOT COMBO:		1		AVG AGE,MO:	181.00		LC AVG SHORE A:	70.40		3 SIGMA-SHORE A:			
	LOT COMBO: 45.		CTPB MFGR: PHILLIPS											
AA	20894.	175.00	0.030	0.000	SS	0	0.050	0.000	SS		MEDIUM	SLIGHT BROWN	74.60	POOR
	# MOTORS IN LOT COMBO:		1		AVG AGE,MO:	175.00		LC AVG SHORE A:	74.60		3 SIGMA-SHORE A:			
	LOT COMBO: 46.		CTPB MFGR: GTR											
AA	20855.	175.00	0.030	0.000	SS	NO	0.050	0.040	VSS	3.	MEDIUM	NORM	68.00	POOR
	# MOTORS IN LOT COMBO:		1		AVG AGE,MO:	175.00		LC AVG SHORE A:	68.00		3 SIGMA-SHORE A:			
	LOT COMBO: 47.		CTPB MFGR: PHILLIPS											
AA	20924.	170.00	0.030	0.000	STCKY	180	0.000	0.000	VSS	4.	MEDIUM	NORM	68.00	POOR
AA	20932.	171.00	0.040	0.000	STCKY	270	0.140	0.090	VS		LIGHT	REDDISH	68.30	POOR
	# MOTORS IN LOT COMBO:		2		AVG AGE,MO:	170.50		LC AVG SHORE A:	68.15		3 SIGMA-SHORE A:	.64		

Figure A-8. SAAS-36 Visual Inspection Report August 30, 1985 to March 30, 1986, Sheet 2 of 3

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
LOT COMBO: 48. CTPB MFGR: GTR														
AA	20953.	171.00	0.060	0.000	VS	90	0.200	0.080	VS	10.	LIGHT	NORM	65.70	VPOOR
AA	20957.	168.00	0.050	0.000	SS	0	0.030	0.180	SS		NONE	NORM	68.00	POOR
# MOTORS IN LOT COMBO: 2						AVG AGE,MO: 169.50			LC AVG SHORE A: 66.85			3 SIGMA-SHORE A: 4.88		
LOT COMBO: 52. CTPB MFGR: GTR														
AA	21051.	161.00	0.050	0.000	VS	180	0.210	0.050	VS	25.	MEDIUM	SLIGHT BROWN	63.60	VPOOR
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 161.00			LC AVG SHORE A: 63.60			3 SIGMA-SHORE A:		
LOT COMBO: 53. CTPB MFGR: GTR														
AA	21067.	160.00	0.080	0.000	STCKY	90	0.100	0.080	VSS	3.	LIGHT	NORM	66.70	VPOOR
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 160.00			LC AVG SHORE A: 66.70			3 SIGMA-SHORE A:		
LOT COMBO: 64. CTPB MFGR: PHILLIPS														
AA	21434.	122.00	0.100	0.000	STCKY	90	0.050	0.000	SS	4.	LIGHT	NORM	71.10	VPOOR
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 122.00			LC AVG SHORE A: 71.10			3 SIGMA-SHORE A:		

		PHILLIPS MOTORS	GTR MOTORS
COUNT		13	11
MOTOR CONDITION:	FAIR	4	2
	POOR	7	5
	VPOOR	2	4

Figure A-8. SAAS-36 Visual Inspection Report August 30, 1985 to March 30, 1986, Sheet 3 of 3

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
	LOT COMBO: 4.	CTPB MFGR: PHILLIPS												
AA	20109.	205.00	0.060	0.030	SS	YES	0.150	0.100	SS		LIGHT	DARK GRAY/RED	71.00	POOR
AA	20105.	217.00	0.040	0.000	STCKY	NO	0.020	0.000	SS		HEAVY	RED/GREEN	75.30	POOR
AA	20111.	217.00	0.080	0.000	SS		0.200	0.030	SS	1.	MEDIUM	DARK GRAY/RED	75.89	POOR
AA	20106.	225.00	0.060	0.010	SS	YES	0.320	0.040	SS	1.	NONE	RED/GRAY	79.44	POOR
	# MOTORS IN LOT COMBO: 4					AVG AGE,MO: 216.00			LC AVG SHORE A: 75.41			3 SIGMA-SHORE A: 10.38		
	LOT COMBO: 7.	CTPB MFGR: GTR												
AA	20081.	218.00	0.100	0.020	STCKY	YES	0.220	0.300	STCKY	10.	MEDIUM	DARK GRAY	66.22	VPOOR
	# MOTORS IN LOT COMBO: 1					AVG AGE,MO: 218.00			LC AVG SHORE A: 66.22			3 SIGMA-SHORE A:		
	LOT COMBO: 8.	CTPB MFGR: GTR												
AA	20144.	193.00	0.020	0.000	NORM	NO	0.020	0.000	VSS	1.	HEAVY	NONE	66.80	FAIR
AA	20126.	214.00	0.080	0.000	STCKY	NO	0.230	0.090	STCKY		HEAVY	NONE	70.50	POOR
AA	20114.	220.00	0.060	0.100	VSS	YES	0.180	0.150	SS	12.	MEDIUM	DARK GRAY/RED	65.89	VPOOR
	# MOTORS IN LOT COMBO: 3					AVG AGE,MO: 209.00			LC AVG SHORE A: 67.73			3 SIGMA-SHORE A: 7.32		
	LOT COMBO: 9.	CTPB MFGR: PHILLIPS												
AA	20143.	216.00	0.030	0.000	VSS	NO	0.180	0.100	VSS		LIGHT	REDDISH	78.40	FAIR
AA	20138.	217.00	0.020	0.010	SS	YES	0.250	0.150	VSS		LIGHT	>iNONE	76.33	FAIR
	# MOTORS IN LOT COMBO: 2					AVG AGE,MO: 216.50			LC AVG SHORE A: 77.37			3 SIGMA-SHORE A: 4.39		
	LOT COMBO: 10.	CTPB MFGR: GTR												
AA	20186.	182.00	0.080	0.030	STCKY	NO	0.000	0.000	NORM	6.	LIGHT	NONE	64.00	POOR
AA	20200.	187.00	0.055	0.000	STCKY	NO	0.030	0.000	NORM	3.	MEDIUM	NONE	70.50	FAIR
AA	20193.	191.00	0.150	0.200	VS		0.050	0.020	STCKY	30.	LIGHT		65.55	VPOOR
AA	20198.	210.00	0.070	0.050	STCKY	YES	0.120	0.010	STCKY	15.	LIGHT	DARK GRAY	65.10	VPOOR
AA	20201.	211.00	0.100	0.000	SS	NO	0.120	0.080	SS	50.	MEDIUM	DARK GRAY	67.66	POOR
AA	20157.	216.00	0.040	0.000	SS		0.180	0.020	SS	20.	NONE	DARK GRAY/RED	65.44	FAIR
	# MOTORS IN LOT COMBO: 6					AVG AGE,MO: 199.50			LC AVG SHORE A: 66.38			3 SIGMA-SHORE A: 7.03		
	LOT COMBO: 11.	CTPB MFGR: GTR												

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 1 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20218.	185.00	0.100	0.000	STCKY	NO	0.050	0.000	STCKY	5.	LIGHT	NONE	71.00	FAIR
AA	20321.	185.00	0.120	0.080	VS		0.320	0.100	VS	15.	MEDIUM	DARK GRAY	66.40	VPOOR
AA	20332.	187.00	0.060	0.020	STCKY	YES	0.100	0.100	STCKY	100.	LIGHT	DARK GRAY/RED	62.20	VPOOR
AA	20217.	189.00	0.030	0.020	STCKY	NO	0.200	0.030	STCKY	12.	LIGHT	REDDISH	70.80	POOR
AA	20214.	206.00	0.120	0.020	VS	YES	0.200	0.060	STCKY	20.	NONE	NORM	59.33	VPOOR
AA	20211.	209.00	0.100	0.040	STCKY	NO	0.150	0.100	STCKY	10.	LIGHT	REDDISH	67.30	POOR
# MOTORS IN LOT COMBO: 6		AVG AGE,MO: 193.50						LC AVG SHORE A: 66.17				3 SIGMA-SHORE A: 13.98		
LOT COMBO: 12.		CTPB MFGR: PHILLIPS												
AA	20183.	187.00	0.070	0.000	STCKY	NO	0.250	0.030	STCKY	1.	MEDIUM	NONE	77.00	POOR
AA	20166.	204.00	0.080	0.020	STCKY		0.220	0.020	STCKY		NONE		72.10	POOR
AA	20159.	212.00	0.050	0.000	STCKY	NO	0.300	0.150	STCKY		LIGHT	GRAY/BROWN	78.30	POOR
# MOTORS IN LOT COMBO: 3		AVG AGE,MO: 201.00						LC AVG SHORE A: 75.60				3 SIGMA-SHORE A: 9.81		
LOT COMBO: 13.		CTPB MFGR: PHILLIPS												
AA	20232.	187.00	0.055	0.000	SS	NO	0.030	0.010	VSS	1.	NONE	NONE	75.40	FAIR
AA	20238.	190.00	0.030	0.000	VSS		0.120	0.050	SS		NONE	DARK GRAY/RED	82.32	FAIR
AA	20235.	200.00	0.070	0.010	SS		0.100	0.150	SS	1.	LIGHT	DARK GRAY	74.40	POOR
AA	20234.	202.00	0.030	0.000	VSS		0.150	0.100	VSS	1.	LIGHT	DARK GRAY/RED	72.33	POOR
AA	20223.	205.00	0.030	0.000	VSS		0.020	0.030	VSS	3.	NONE		72.69	FAIR
AA	20212.	217.00	0.090	0.010	STCKY	YES	0.300	0.140	STCKY	10.	NONE	NONE	78.78	VPOOR
# MOTORS IN LOT COMBO: 6		AVG AGE,MO: 200.17						LC AVG SHORE A: 76.02				3 SIGMA-SHORE A: 11.52		
LOT COMBO: 14.		CTPB MFGR: PHILLIPS												
AA	20269.	185.00	0.030	0.000	VSS	NO	0.030	0.000	NORM		NONE	REDDISH	78.00	FAIR
AA	20276.	187.00	0.070	0.040	STCKY		0.030	0.010	SS	3.	LIGHT		77.11	POOR
AA	20283.	188.00	0.020	0.000	SS		0.180	0.030	STCKY	4.	NONE	DARK GRAY	72.80	FAIR
AA	20259.	189.00	0.040	0.000	SS		0.180	0.120	SS	6.	LIGHT		71.50	FAIR
# MOTORS IN LOT COMBO: 4		AVG AGE,MO: 187.25						LC AVG SHORE A: 74.85				3 SIGMA-SHORE A: 9.56		
LOT COMBO: 15.		CTPB MFGR: PHILLIPS												
AA	20267.	186.00	0.070	0.000	SS	NO	0.240	0.010	VSS		MEDIUM	DARK GRAY/RED	84.11	POOR
AA	20240.	188.00	0.030	0.010	VSS	NO	0.030	0.030	SS	3.	NONE	REDDISH	82.33	FAIR
AA	20244.	193.00	0.080	0.010	SS	YES	0.260	0.030	STCKY		LIGHT		76.80	POOR
AA	20247.	195.00	0.100	0.020	STCKY	YES	0.210	0.040	VS	1.	LIGHT	DARK GRAY/RED	77.60	VPOOR
AA	20264.	209.00	0.030	0.000	SS		0.080	0.000	VSS	1.	NONE	DARK GRY/BRWN	82.33	POOR
AA	20292.	214.00	0.060	0.030	STCKY	YES	0.600	0.060	STCKY	15.	LIGHT		65.78	VPOOR

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 2 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION

\# MOTORS IN LOT COMBO: 6 AVG AGE,MO: 197.50 LC AVG SHORE A: 78.16 3 SIGMA-SHORE A: 20.15

LOT COMBO: 16. CTPB MFGR: PHILLIPS

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20315.	180.00	0.100	0.020	STCKY	NO	0.300	0.100	STCKY		MEDIUM	DARK GRAY	80.00	POOR
AA	20331.	182.00	0.030	0.000	NORM	NO	0.200	0.030	SS	6.	LIGHT	NONE	76.00	POOR
AA	20327.	184.00	0.030	0.010	NORM	NO	0.030	0.030	VSS		LIGHT	NONE	75.77	FAIR
AA	20356.	184.00	0.080	0.030	STCKY		0.100	0.060	SS		LIGHT	DARK GRAY	74.10	POOR
AA	20361.	187.00	0.030	0.010	NORM		0.200	0.100	VSS	2.	NONE	DARK GRAY	66.20	FAIR
AA	20338.	189.00	0.010	0.000	VSS		0.150	0.030	VSS	14.	LIGHT	REDDISH	68.70	FAIR
AA	20335.	193.00	0.030	0.000	VSS		0.250	0.150	VSS	1.	NONE	REDDISH	71.20	FAIR
AA	20353.	198.00	0.030	0.000	NORM		0.280	0.120	SS	10.	NONE	DARK GRAY	69.56	POOR
AA	20337.	199.00	0.010	0.000	NORM		0.210	0.050	STCKY	10.	LIGHT	BROWN/GRAY	71.56	FAIR
AA	20325.	203.00	0.020	0.000	VSS	NO	0.220	0.100	SS		NONE	DARK GRAY	72.30	FAIR
AA	20320.	205.00	0.100	0.010	SS	YES	0.400	0.200	SS	20.	LIGHT	REDDISH	73.20	VPOOR

\# MOTORS IN LOT COMBO: 11 AVG AGE,MO: 191.27 LC AVG SHORE A: 72.55 3 SIGMA-SHORE A: 11.79

LOT COMBO: 17. CTPB MFGR: PHILLIPS

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20296.	180.00	0.030	0.000	STCKY		0.100	0.040	STCKY	6.	LIGHT		68.00	FAIR
AA	20289.	184.00	0.030	0.010	SS	NO	0.030	0.010	STCKY	3.	NONE	NONE	63.20	FAIR
AA	20301.	190.00	0.100	0.050	STCKY	YES	0.180	0.150	STCKY	25.	NONE		61.60	VPOOR
AA	20299.	191.00	0.060	0.000	SS	YES	0.250	0.150	STCKY	10.	LIGHT	DARK GRAY/RED	60.10	POOR
AA	20293.	198.00	0.040	0.010	VSS		0.200	0.030	SS	6.	NONE	DARK GRAY	63.67	FAIR
AA	20300.	200.00	0.060	0.100	VS	YES	0.340	0.100	VS	10.	NONE	DARK GRAY	60.22	VPOOR
AA	20303.	201.00	0.070	0.000	STCKY		0.380	0.020	STCKY		LIGHT	DARK GRAY	65.56	POOR
AA	20291.	203.00	0.040	0.030	STCKY	YES	0.240	0.020	VS	10.	LIGHT	DARK GRAY	61.33	VPOOR
AA	20290.	204.00	0.090	0.010	STCKY	NO	0.280	0.100	STCKY	50.	NONE	NORM	66.90	POOR
AA	20309.	204.00	0.160	0.010	STCKY	YES	0.220	0.200	STCKY	25.	LIGHT	DARK GRAY	62.20	VPOOR

\# MOTORS IN LOT COMBO: 10 AVG AGE,MO: 195.50 LC AVG SHORE A: 63.28 3 SIGMA-SHORE A: 8.25

LOT COMBO: 18. CTPB MFGR: PHILLIPS

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20386.	178.00	0.030	0.010	NORM	NO	0.030	0.010	VSS	6.	MEDIUM	NONE	71.50	FAIR
AA	20352.	182.00	0.070	0.030	SS	NO	0.150	0.030	STCKY	6.	LIGHT	NONE	73.80	POOR
AA	20384.	182.00	0.030	0.000	NORM		0.040	0.010	NORM	8.	NONE	DARK GRAY/RED	75.66	FAIR
AA	20378.	184.00	0.030	0.010	VSS		0.100	0.050	SS	2.	NONE	DARK GRAY	67.80	POOR
AA	20362.	188.00	0.060	0.030	STCKY	YES	0.300	0.100	STCKY	10.	LIGHT	DARK GRAY/RED	66.80	VPOOR
AA	20381.	190.00	0.030	0.000	SS		0.100	0.050	SS	12.	LIGHT	DARK GRAY	69.77	POOR
AA	20383.	192.00	0.200	0.000	NORM		0.100	0.000	NORM	1.	LIGHT		68.00	POOR
AA	20396.	192.00	0.030	0.000	NORM		0.200	0.010	VSS	3.	NONE		66.00	FAIR
AA	20364.	193.00	0.040	0.000	VSS	YES	0.240	0.100	STCKY		NONE	DARK GRAY	70.50	VPOOR
AA	20382.	195.00	0.030	0.000	NORM		0.050	0.000	NORM		NONE	DARK GRAY	71.89	FAIR

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 3 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
# MOTORS IN LOT COMBO: 10					AVG AGE,MO: 187.60				LC AVG SHORE A: 70.17			3 SIGMA-SHORE A: 9.35		
LOT COMBO: 19.			CTPB MFGR: GTR											
AA	20357.	180.00	0.040	0.010	NORM	NO	0.000	0.010	SS	9.	HEAVY	NONE	69.00	POOR
AA	20355.	18'.00	0.090	0.000	VSS	NO	0.280	0.010	SS	3.	LIGHT	NONE	70.00	POOR
AA	20399.	182.00	0.060	0.000	VSS		0.080	0.010	VSS	15.	NONE	DARK GRAY	63.60	FAIR
AA	20343.	185.00	0.070	0.020	VSS		0.100	0.040	SS	8.	NONE		67.20	FAIR
AA	20392.	186.00	0.030	0.150	NORM	YES	0.200	0.100	SS	30.	NONE		60.00	POOR
AA	20350.	187.00	0.090	0.050	STCKY	YES	0.260	0.140	VS	25.	LIGHT		64.20	VPOOR
AA	20370.	189.00	0.060	0.000	VS	YES	0.400	0.010	VS	20.	LIGHT	DARK GRAY	61.66	VPOOR
AA	20346.	191.00	0.030	0.000	VSS		0.200	0.080	VSS	5.	NONE		63.50	FAIR
AA	20369.	197.00	0.080	0.050	STCKY	YES	0.400	0.010	STCKY	10.	NONE	NONE	62.56	VPOOR
AA	20389.	212.40	0.060	0.010	SS	YES	0.180	0.080	SS	20.	MEDIUM	DARK GRAY/RED	70.78	POOR
AA	20394.	215.00	0.040	0.040	STCKY	YES	0.200	0.080	SS	10.	MEDIUM	DARK GRAY	72.30	VPOOR
# MOTORS IN LOT COMBO: 11					AVG AGE,MO: 191.40				LC AVG SHORE A: 65.91			3 SIGMA-SHORE A: 12.37		
LOT COMBO: 20.			CTPB MFGR: GTR											
AA	20403.	178.00	0.030	0.010	SS	NO	0.020	0.000	NORM	20.	LIGHT	NONE	70.00	FAIR
AA	20415.	179.00	0.070	0.000	SS	NO	0.250	0.200	SS	12.	NONE	REDDISH	67.60	POOR
AA	20411.	180.00	0.060	0.040	STCKY		0.180	0.200	VSS	3.	MEDIUM	REDDISH	63.80	POOR
AA	20368.	185.00	0.050	0.010	VS		0.400	0.020	STCKY	5.	NONE	DARK GRAY	63.00	POOR
AA	20401.	186.00	0.060	0.020	VS		0.200	0.100	SS	12.	HEAVY	DARK GRAY/RED	63.80	VPOOR
AA	20400.	188.00	0.030	0.010	SS		0.100	0.010	SS	20.	LIGHT	DARK GRAY	65.60	FAIR
AA	20413.	202.00	0.040	0.020	VS	YES	0.350	0.200	VS	30.	LIGHT	NNE	64.30	VPOOR
AA	20409.	209.70	0.060	0.100	VSS	YES	0.180	0.100	VSS	4.	LIGHT	NORM	69.11	VPOOR
AA	20408.	210.00	0.030	0.020	SS	NO	0.200	0.050	SS	6.	LIGHT	NORM	68.22	FAIR
AA	20402.	211.00	0.100	0.100	SS	YES	0.300	0.100	VSS	15.	NONE	NONE	70.11	VPOOR
# MOTORS IN LOT COMBO: 10					AVG AGE,MO: 192.87				LC AVG SHORE A: 66.55			3 SIGMA-SHORE A: 8.29		
LOT COMBO: 21.			CTPB MFGR: PHILLIPS											
AA	20374.	185.00	0.010	0.000	NORM		0.100	0.010	VSS		NONE	DARK GRAY	69.66	FAIR
AA	20429.	186.00	0.020	0.000	NORM		0.160	0.100	VSS		LIGHT	DARK GRAY/RED	68.80	POOR
AA	20432.	189.00	0.030	0.000	VSS	YES	0.320	0.100	SS	10.	LIGHT	REDDISH	76.50	POOR
AA	20437.	191.00	0.030	0.000	SS		0.250	0.010	SS	1.	MEDIUM	REDDISH	72.67	POOR
AA	20449.	191.00	0.030	0.010	SS		0.300	0.100	STCKY	2.	LIGHT	DARK GRAY	76.11	POOR
AA	20376.	192.00	0.100	0.000	NORM		0.100	0.000	NORM	6.	LIGHT	REDDISH	74.10	FAIR
AA	20446.	192.00	0.050	0.020	SS		0.400	0.250	VSS	10.	LIGHT	REDDISH	74.00	POOR
AA	20377.	200.00	0.010	0.000	VSS	NO	0.000	0.000	VSS		MEDIUM	DARK GRAY/RED	78.30	FAIR
AA	20456.	204.00	0.020	0.000	NORM	NO	0.200	0.080	STCKY		HEAVY	RED SPOTS	81.11	POOR
AA	20454.	205.00	0.030	0.010	VSS	NO	0.220	0.120	SS	10.	LIGHT	DARK GRAY/RED	81.11	VPOOR
AA	20452.	207.00	0.030	0.000	NORM	NO	0.340	0.0?0	SS		LIGHT	GRAY	77.11	POOR

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 4 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
# MOTORS IN LOT COMBO: 11		AVG AGE,MO: 194.91		LC AVG SHORE A: 75.41		3 SIGMA-SHORE A: 12.22								
LOT COMBO: 22.		CTPB MFGR: GTR												
AA	20436.	174.00	0.030	0.000	SS	YES	0.200	0.100	SS	5.	LIGHT	DARK GRAY/RED	65.30	POOR
AA	20375.	178.00	0.040	0.000	SS	NO	0.150	0.010	STCKY	4.	LIGHT	NONE	74.00	FAIR
AA	20425.	180.00	0.030	0.010	SS		0.040	0.030	SS	15.	NONE		69.80	FAIR
AA	20423.	181.00	0.030	0.010	SS		0.100	0.010	SS	15.	LIGHT		73.50	FAIR
AA	20439.	186.00	0.030	0.010	VSS		0.150	0.100	SS	12.	MEDIUM		69.90	POOR
AA	20442.	188.00	0.030	0.010	VSS		0.160	0.120	SS	10.	HEAVY		71.60	VPOOR
AA	20426.	193.00	0.010	0.000	NORM		0.100	0.060	SS	15.	MEDIUM	NONE	68.67	FAIR
AA	20421.	194.00	0.050	0.010	STCKY		0.180	0.100	STCKY	20.	MEDIUM	NONE	67.56	POOR
AA	20438.	210.00	0.060	0.000	SS	YES	0.380	0.100	STCKY		LIGHT	DARK GRAY	72.56	VPOOR
AA	20443.	210.00	0.030	0.040	SS	YES	0.220	0.020	SS	10.	MEDIUM		74.78	VPOOR
# MOTORS IN LOT COMBO: 10		AVG AGE,MO: 189.60		LC AVG SHORE A: 70.77		3 SIGMA-SHORE A: 9.18								
LOT COMBO: 23.		CTPB MFGR: PHILLIPS												
AA	20549.	190.00	0.010	0.000	NORM	NO	0.120	0.020	VSS	6.	LIGHT	REDDISH	79.45	FAIR
AA	20509.	198.00	0.060	0.010	SS	NO	0.200	0.020	STCKY	2.	VHEAVY	REDDISH	78.55	POOR
AA	20482.	199.00	0.010	0.000	VSS	NO	0.100	0.010	VSS	6.	HEAVY	DARK GRAY	79.32	FAIR
AA	20477.	200.00	0.035	0.000	SS	NO	0.300	0.010	SS		HEAVY	BROWN/RED	81.33	POOR
AA	20466.	207.00	0.030	0.000	VSS	NO	0.200	0.080	SS	3.	LIGHT	GRAY/GREEN	84.00	FAIR
AA	20469.	209.00	0.010	0.000	NORM	NO	0.140	0.010	VSS	4.	MEDIUM	RED	81.00	FAIR
# MOTORS IN LOT COMBO: 6		AVG AGE,MO: 200.50		LC AVG SHORE A: 80.61		3 SIGMA-SHORE A: 5.91								
LOT COMBO: 24.		CTPB MFGR: GTR												
AA	20485.	190.00	0.060	0.010	SS	NO	0.180	0.000	STCKY	15.	MEDIUM	BROWN/GRAY	67.00	POOR
AA	20476.	192.00	0.020	0.000	NORM	NO	0.150	0.040	VSS	10.	HEAVY	DARK GRAY/RED	66.22	POOR
AA	20488.	192.00	0.020	0.000	VSS	NO	0.030	0.000	VSS	5.	MEDIUM	DARK GRAY	66.33	FAIR
AA	20473.	194.00	0.030	0.000	SS	NO	0.080	0.030	SS		VHEAVY	DARK GRAY	67.20	VPOOR
AA	20481.	197.00	0.030	0.000	NORM	YES	0.180	0.020	SS	30.	MEDIUM	DARK GRAY	66.10	POOR
AA	20489.	197.00	0.040	0.000	VSS	YES	0.120	0.050	VSS	6.	LIGHT	DARK GRAY	71.78	POOR
AA	20480.	207.50	0.030	0.000	VSS	NO	0.180	0.040	VSS	20.	NONE	NONE	70.67	FAIR
AA	20483.	209.00	0.060	0.000	SS	NO	0.220	0.020	SS	4.	HEAVY	NORM	73.22	POOR
AA	20490.	209.80	0.050	0.000	VSS	NO	0.320	0.020	VSS		LIGHT	NORM	71.77	POOR
AA	20478.	212.30	0.030	0.010	SS	NO	0.210	0.060	VSS	5.	HEAVY	GRAY	72.33	POOR
# MOTORS IN LOT COMBO: 10		AVG AGE,MO: 200.06		LC AVG SHORE A: 69.26		3 SIGMA-SHORE A: 8.77								
LOT COMBO: 25.		CTPB MFGR: PHILLIPS												

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 5 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20505.	177.00	0.000	0.000	NORM	NO	0.100	0.015	STCKY		MEDIUM	NONE	76.00	FAIR
AA	20496.	178.00	0.000	0.000	STCKY		0.070	0.000	NORM		NONE		71.00	FAIR
AA	20502.	184.00	0.300	0.200	NORM		0.180	0.060	SS	10.	HEAVY	DARK GRAY	72.00	VPOOR
20	20506.	192.00	0.030	0.000	NORM	NO	0.400	0.030	SS	10.	HEAVY	DARK GRAY/RED	78.20	POOR
AA	20510.	192.00	0.020	0.000	NORM		0.100	0.000	VSS		HEAVY	DARK GRAY/RED	76.40	FAIR
AA	20507.	196.00	0.000	0.000	NORM	NO	0.000	0.000	NORM		VHEAVY	REDDISH	80.77	POOR
AA	20497.	201.00	0.020	0.010	VSS	NO	0.080	0.000	VSS		MEDIUM	REDDISH	76.00	FAIR
AA	20501.	201.00	0.000	0.000	NORM	NO	0.160	0.100	STCKY		HEAVY	NORMAL	79.40	POOR
AA	20475.	205.00	0.025	0.000	VSS	NO	0.180	0.080	VSS	6.	MEDIUM	NONE	78.55	FAIR
AA	20457.	212.00	0.000	0.000	NORM	NO	0.050	0.000	VSS	1.	LIGHT	GREENISH	82.99	FAIR

\# MOTORS IN LOT COMBO: 10 AVG AGE,MO: 193.80 LC AVG SHORE A: 77.13 3 SIGMA-SHORE A: 11.09

LOT COMBO: 26. CTPB MFGR: GTR

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20535.	181.00	0.000	0.000	NORM		0.000	0.000	NORM	10.	LIGHT		60.77	FAIR
AA	20521.	184.00	0.010	0.000	NORM		0.020	0.000	NORM	50.	MEDIUM	R[illegible]	63.78	FAIR
AA	20511.	187.00	0.040	0.000	NORM	NO	0.100	0.020	SS	30.	HEAVY	RE[illegible]	64.33	FAIR
AA	20518.	188.00	0.020	0.000	VSS	NO	0.030	0.010	SS	50.	VHEAVY	DA[illegible]RED	67.80	FAIR
AA	20527.	194.00	0.000	0.000	VSS	NO	0.000	0.000	VSS	35.	LIGHT	DAR[illegible]	65.44	FAIR
AA	20532.	194.00	0.000	0.000	NORM	NO	0.010	0.000	VSS	50.	LIGHT	GRAY/RED	65.33	FAIR
AA	20493.	199.00	0.040	0.010	VSS	NO	0.080	0.010	VSS	10.	LIGHT	NONE	68.89	FAIR
AA	20495.	199.00	0.080	0.020	VSS	YES	0.140	0.060	SS	3.	LIGHT	RED	65.33	POOR
AA	20523.	200.30	0.040	0.010	VSS	NO	0.380	0.030	SS	12.	MEDIUM	NORM	63.80	FAIR
AA	20519.	201.00	0.000	0.000	NORM	NO	0.000	0.030	NORM	20.	HEAVY	DARK GRAY	68.70	FAIR
AA	20516.	205.30	0.030	0.000	VSS	NO	0.150	0.180	SS	6.	HEAVY	GRAY/RED	70.30	POOR
AA	20526.	206.80	0.000	0.000	NORM	NO	0.020	0.000	NORM	30.	LIGHT	NORM	68.99	FAIR
AA	20514.	207.70	0.030	0.010	NORM	NO	0.140	0.060	SS	40.	HEAVY	REDDISH	73.11	POOR
AA	20515.	208.20	0.030	0.000	NORM	NO	0.000	0.000	NORM	20.	LIGHT	NORM	69.66	FAIR

\# MOTORS IN LOT COMBO: 14 AVG AGE,MO: 196.81 LC AVG SHORE A: 66.87 3 SIGMA-SHORE A: 9.87

LOT COMBO: 27. CTPB MFGR: GTR

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20553.	176.00	0.010	0.000	NORM		0.100	0.000	NORM	30.	LIGHT	REDDISH	63.88	FAIR
AA	20540.	178.00	0.000	0.000	NORM		0.030	0.000	NORM	30.	VHEAVY	REDDISH	67.00	FAIR
AA	20546.	180.00	0.000	0.000	NORM		0.020	0.000	SS	10.	MEDIUM		61.33	FAIR
AA	20544.	184.00	0.000	0.000	NORM	NO	0.030	0.000	NORM	20.	MEDIUM	DARK GRAY/RED	66.90	FAIR
AA	20551.	185.00	0.010	0.000	NORM	NO	0.080	0.000	VSS	1.	LIGHT	REDDISH	65.10	FAIR
AA	20539.	188.00	0.000	0.000	NORM		0.000	0.000	NORM	30.	MEDIUM	REDDISH	62.88	FAIR
AA	20536.	191.00	0.010	0.000	NORM		0.010	0.000	NORM	20.	HEAVY	RED/BROWN	70.11	FAIR
AA	20528.	192.00	0.000	0.000	NORM	NO	0.020	0.000	NORM	15.	LIGHT	DARK GRAY	66.40	FAIR
AA	20534.	199.00	0.030	0.000	NORM	NO	0.000	0.000	NORM	10.	MEDIUM	REDDISH	67.67	FAIR
AA	20530.	203.00	0.000	0.000	NORM	NO	0.000	0.000	VSS	12.	NONE	NORM	72.33	FAIR
AA	20538.	204.70	0.000	0.000	NORM	NO	0.000	0.000	NORM	6.	NONE	NORM	73.44	FAIR
AA	20542.	205.00	0.000	0.000	NORM	NO	0.000	0.000	NORM	10.	LIGHT	NORM	65.90	FAIR
AA	20548.	205.00	0.030	0.010	NORM	NO	0.000	0.000	NORM	20.	LIGHT	NORM	67.70	FAIR
AA	20533.	205.80	0.000	0.000	NORM	NO	0.000	0.000	NORM	30.	VHEAVY	NORM	70.99	FAIR

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 6 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION

MOTORS IN LOT COMBO: 14 AVG AGE,MO: 192.61 LC AVG SHORE A: 67.26 3 SIGMA-SHORE A: 10.51

LOT COMBO: 28. CTPB MFGR: GTR

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20579.	166.00	0.050	0.000	NORM		0.050	0.000	NORM	10.	HEAVY	DARK GRAY/RED	60.80	FAIR
AA	20520.	199.30	0.040	0.010	NORM	NO	0.040	0.100	VSS	30.	HEAVY	NORMAL	64.10	POOR
AA	20584.	201.00	0.040	0.000	NORM	NO	0.100	0.000	NORM	3.	MEDIUM	SLIGHT RED	65.40	POOR
AA	20591.	201.00	0.030	0.010	VSS	NO	0.000	0.000	VSS	8.	HEAVY	NO	66.10	FAIR
AA	20586.	203.00	0.040	0.000	SS	0	0.100	0.020	VSS	15.	LIGHT	SLIGHT BROWN	66.90	FAIR
AA	20576.	204.00	0.050	0.050	SS	180	0.300	0.100	SS	25.	LIGHT	NORM	67.50	POOR

MOTORS IN LOT COMBO: 6 AVG AGE,MO: 195.72 LC AVG SHORE A: 65.13 3 SIGMA-SHORE A: 7.30

LOT COMBO: 29. CTPB MFGR: GTR

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20557.	166.00	0.010	0.010	VSS		0.020	0.000	SS	24.	LIGHT		64.20	FAIR
AA	20562.	176.00	0.040	0.010	VSS		0.150	0.000	SS	10.	MEDIUM	DARK GRAY/RED	63.33	POOR
AA	20563.	177.00	0.030	0.000	VSS		0.020	0.000	NORM	16.	MEDIUM	DARK GRAY/RED	62.44	FAIR
AA	20558.	181.00	0.030	0.000	NORM	NO	0.050	0.000	VSS	3.	HEAVY	GRAY/RED/BRWN	61.89	FAIR
AA	20569.	190.00	0.050	0.010	SS	NO	0.040	0.000	VSS	15.	MEDIUM	RED/GRAY	63.44	FAIR
AA	20573.	193.00	0.035	0.050	STCKY	YES	0.160	0.040	SS	20.	MEDIUM	NORMAL	61.22	VPOOR
AA	20594.	193.60	0.030	0.020	VSS	NO	0.120	0.060	VSS	10.	MEDIUM	NONE	67.89	FAIR
AA	20575.	199.30	0.040	0.010	VSS	NO	0.100	0.010	VSS	20.	HEAVY	DARK GRAY	68.66	FAIR
AA	20574.	200.40	0.030	0.200	SS	YES	0.100	0.010	SS	10.	HEAVY	NORM	70.66	POOR
AA	20561.	200.80	0.040	0.010	VSS	NO	0.200	0.120	SS	20.	MEDIUM	GRAY	70.22	POOR
AA	20565.	203.00	0.030	0.000	NORM	NO	0.100	0.000	NORM	5.	MEDIUM	NORM	64.00	FAIR
AA	20572.	203.00	0.040	0.020	NORM	YES	0.000	0.000	NORM	12.	LIGHT	NORM	60.30	FAIR
AA	20593.	204.00	0.030	0.000	VSS	NO	0.100	0.000	VSS	10.	MEDIUM	NORM	61.40	POOR
AA	20543.	207.00	0.010	0.000	NORM	NO	0.010	0.000	SS	20.	LIGHT	RED MOTTLE	65.80	FAIR
AA	20555.	208.00	0.040	0.000	VSS	N	0.150	0.050	SS	10.	HEAVY	REDDISH	68.10	POOR

MOTORS IN LOT COMBO: 15 AVG AGE,MO: 193.47 LC AVG SHORE A: 64.90 3 SIGMA-SHORE A: 10.25

LOT COMBO: 30. CTPB MFGR: PHILLIPS

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20617.	170.00	0.200	0.000	NORM		0.100	0.000	NORM	4.	VHEAVY	REDDISH	71.80	POOR
AA	20603.	192.00	0.000	0.000	NORM	NO	0.020	0.000	VSS	6.	LIGHT	DARK GRAY	80.00	FAIR
AA	20601.	192.60	0.030	0.000	VSS	NO	0.080	0.050	VSS		VHEAVY	RED	79.89	FAIR
AA	20606.	193.00	0.020	0.010	VSS	NO	0.080	0.000	VSS	3.	MEDIUM	GRAY/RED	78.56	FAIR
AA	20616.	193.60	0.030	0.000	NORM	NO	0.180	0.020	VSS	2.	LIGHT	GRN/GRAY/RED	82.10	POOR
AA	20613.	194.00	0.030	0.000	VSS	NO	0.000	0.000	VSS	3.	VHEAVY	DARK GRAY	81.67	POOR
AA	20598.	204.00	0.000	0.000	VSS	NO	0.000	0.000	SS		LIGHT	RED-BROWN	76.10	FAIR
AA	20514.	207.00	0.040	0.000	STCKY	180	0.000	0.000	VSS	5.	MEDIUM	BROWN	73.20	POOR
AA	20602.	208.00	0.000	0.000	VSS	0	0.100	0.050	SS	5.	HEAVY	SLIGHT BROWN	77.60	POOR

MOTORS IN LOT COMBO: 9 AVG AGE,MO: 194.91 LC AVG SHORE A: 77.88 3 SIGMA-SHORE A: 10.78

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 7 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
LOT COMBO: 31. CTPB MFGR: GTR														
AA	20615.	157.00	0.030	0.010	SS	NO	0.030	0.000	NORM		HEAVY	DARK GRAY/RED	64.60	POOR
AA	20562.	193.00	0.110	0.050	STCKY	180	0.100	0.070	SS	10.	HEAVY	NORM	63.90	VPOOR
AA	20512.	207.00	0.050	0.000	STCKY	180	0.200	0.200	STCKY	2.	MEDIUM	NORM	62.30	VPOOR
# MOTORS IN LOT COMBO: 3		AVG AGE,MO: 185.67					LC AVG SHORE A: 63.60			3 SIGMA-SHORE A: 3.54				
LOT COMBO: 32. CTPB MFGR: PHILLIPS														
AA	20635.	156.00	0.000	0.000	NORM	0	0.000	0.010	NORM	2.	VHEAVY	REDDISH	72.44	FAIR
AA	20626.	160.00	0.000	0.000	NORM	0	0.010	0.000	NORM		HEAVY	DARK GRAY/RED	69.80	FAIR
AA	20646.	190.70	0.020	0.000	VSS	NO	0.000	0.030	NORM	10.	LIGHT	RED STREAKS	77.67	FAIR
AA	20633.	192.30	0.030	0.000	NORM	0	0.000	0.000	VSS	1.	MEDIUM	REDDISH	73.67	POOR
AA	20657.	194.00	0.030	0.000	NORM	NO	0.020	0.030	NORM	5.	NONE	REDISH-GREY	71.00	FAIR
AA	20629.	197.00	0.060	0.000	STCKY	0	0.100	0.010	SS	10.	HEAVY	BRN MOTTLING	72.40	VPOOR
AA	20645.	199.00	0.040	0.000	STCKY	NO	0.100	0.050	SS		LIGHT	NORM	74.20	POOR
AA	20630.	204.00	0.020	0.000	VSS	0	0.050	0.000	VSS	5.	HEAVY	BROWN STREAKS	75.00	FAIR
AA	20631.	210.00	0.040	0.000	NORM	0	0.150	0.030	SS	2.	HEAVY	REDDISH	70.50	POOR
# MOTORS IN LOT COMBO: 9		AVG AGE,MO: 189.22					LC AVG SHORE A: 72.96			3 SIGMA-SHORE A: 7.41				
LOT COMBO: 33. CTPB MFGR: GTR														
AA	20647.	160.00	0.010	0.000	VSS		0.030	0.000	NORM	20.	HEAVY	REDDISH	55.20	POOR
AA	20637.	163.00	0.030	0.000	NORM		0.030	0.000	VSS	10.	VHEAVY	REDDISH	59.60	POOR
AA	20666.	172.00	0.040	0.000	NORM		0.050	0.000	NORM	20.	MEDIUM	DARK GRAY/RED	62.11	FAIR
AA	20672.	173.00	0.000	0.000	NORM	NO	0.000	0.000	NORM	20.	HEAVY	DARK GRAY/RED	68.50	FAIR
AA	20668.	178.00	0.030	0.000	VSS	NO	0.080	0.000	VSS	20.	MEDIUM	NONE	61.67	FAIR
AA	20636.	184.00	0.020	0.010	VSS	180	0.100	0.020	VSS	20.	VHEAVY	DARK GRAY/RED	65.66	POOR
AA	20638.	189.00	0.030	0.010	VSS	NO	0.200	0.100	VSS	6.	VHEAVY	GRAY/RED	69.89	FAIR
# MOTORS IN LOT COMBO: 7		AVG AGE,MO: 174.14					LC AVG SHORE A: 63.23			3 SIGMA-SHORE A: 15.46				
LOT COMBO: 34. CTPB MFGR: GTR														
AA	20710.	185.80	0.060	0.020	VSS	NO	0.040	0.000	VSS	40.	MEDIUM	REDDISH	64.99	FAIR
AA	20706.	187.00	0.040	0.000	SS	0	0.000	0.000	VSS	20.	LIGHT	NORM	65.60	FAIR
AA	20687.	196.00	0.000	0.000	VSS	0	0.000	0.000	VSS	24.	MEDIUM	SLIGHT RED	67.20	FAIR
# MOTORS IN LOT COMBO: 3		AVG AGE,MO: 189.60					LC AVG SHORE A: 65.93			3 SIGMA-SHORE A: 3.42				
LOT COMBO: 36. CTPB MFGR: GTR														

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 8 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20725.	183.70	0.040	0.000	NORM	NO	0.000	0.000	NORM	15.	HEAVY	DARK GRAY	67.66	FAIR
AA	20717.	188.00	0.020	0.000	SS	0	0.050	0.000	SS	40.	LIGHT	NORM	69.00	FAIR

\# MOTORS IN LOT COMBO: 2 AVG AGE,MO: 185.85 LC AVG SHORE A: 68.33 3 SIGMA-SHORE A: 2.84

LOT COMBO: 37. CTPB MFGR: GTR

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20740.	181.50	0.020	0.000	NORM	NO	0.000	0.000	NORM	4.	NONE	REDDISH	70.44	FAIR
AA	20750.	186.00	0.030	0.000	VSS	YES	0.000	0.000	VSS	7.	MEDIUM	REDDISH	69.10	FAIR

\# MOTORS IN LOT COMBO: 2 AVG AGE,MO: 183.75 LC AVG SHORE A: 69.77 3 SIGMA-SHORE A: 2.84

LOT COMBO: 38. CTPB MFGR: GTR

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20786.	185.00	0.030	0.000	VSS	-	0.000	0.000	VSS	10.	MEDIUM	REDDISH	78.50	POOR

\# MOTORS IN LOT COMBO: 1 AVG AGE,MO: 185.00 LC AVG SHORE A: 78.50 3 SIGMA-SHORE A:

LOT COMBO: 39. CTPB MFGR: PHILLIPS

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20760.	185.00	0.000	0.000	VSS	NO	0.100	0.000	SS	1.	HEAVY	RED-BROWN	74.60	FAIR

\# MOTORS IN LOT COMBO: 1 AVG AGE,MO: 185.00 LC AVG SHORE A: 74.60 3 SIGMA-SHORE A:

LOT COMBO: 41. CTPB MFGR: PHILLIPS

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20808.	177.00	0.000	0.000	NORM	0	0.000	0.000	NORM	5.	NONE	REDDISH-GREY	80.50	POOR
AA	20801.	184.00	0.000	0.000	VSS	0	0.000	0.000	VSS	5.	MEDIUM	NORM	82.90	FAIR
AA	20810.	184.00	0.000	0.000	SS	0	0.150	0.000	SS	1.	LIGHT	NORM	74.30	POOR

\# MOTORS IN LOT COMBO: 3 AVG AGE,MO: 181.67 LC AVG SHORE A: 79.23 3 SIGMA-SHORE A: 13.31

LOT COMBO: 42. CTPB MFGR: GTR

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20874.	159.50	0.030	0.020	VSS	NO	0.020	0.000	NORM	2.	HEAVY	GRAY\	64.67	POOR

\# MOTORS IN LOT COMBO: 1 AVG AGE,MO: 159.50 LC AVG SHORE A: 64.67 3 SIGMA-SHORE A:

LOT COMBO: 43. CTPB MFGR: PHILLIPS

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AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
AA	20318.	181.00	0.030	0.030	STICKY	270	0.100	0.050	SS		MEDIUM	REDDISH-BROWN	70.40	VPOOR

\# MOTORS IN LOT COMBO: 1 AVG AGE,MO: 181.00 LC AVG SHORE A: 70.40 3 SIGMA-SHORE A:

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 9 of 11

AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
LOT COMBO: 45. CTPB MFGR: PHILLIPS														
AA	20894.	175.00	0.030	0.000	SS	0	0.050	0.000	SS		MEDIUM	SLIGHT BROWN	74.60	POOR
# MOTORS IN LOT COMBO: 1	AVG AGE,MO: 175.00	LC AVG SHORE A: 74.60	3 SIGMA-SHORE A:											
LOT COMBO: 46. CTPB MFGR: GTR														
AA	20855.	175.00	0.030	0.000	SS	NO	0.050	0.040	VSS	3.	MEDIUM	NORM	68.00	POOR
# MOTORS IN LOT COMBO: 1	AVG AGE,MO: 175.00	LC AVG SHORE A: 68.00	3 SIGMA-SHORE A:											
LOT COMBO: 47. CTPB MFGR: PHILLIPS														
AA	20924.	170.00	0.030	0.000	STCKY	180	0.000	0.000	VSS	4.	MEDIUM	NORM	68.00	POOR
AA	20932.	171.00	0.040	0.000	STCKY	270	0.140	0.090	VS		LIGHT	REDDISH	68.30	POOR
# MOTORS IN LOT COMBO: 2	AVG AGE,MO: 170.50	LC AVG SHORE A: 68.15	3 SIGMA-SHORE A: .64											
LOT COMBO: 48. CTPB MFGR: GTR														
AA	20957.	168.00	0.050	0.000	SS	0	0.030	0.180	SS		NONE	NORM	68.00	POOR
AA	20953.	171.00	0.060	0.000	VS	90	0.200	0.080	VS	10.	LIGHT	NORM	65.70	VPOOR
# MOTORS IN LOT COMBO: 2	AVG AGE,MO: 169.50	LC AVG SHORE A: 66.85	3 SIGMA-SHORE A: 4.88											
LOT COMBO: 52. CTPB MFGR: GTR														
AA	21049.	140.00	0.080	0.010	VSS	NO	0.180	0.120	SS	15.	NONE	GRAY	66.55	POOR
AA	21051.	161.00	0.050	0.000	VS	180	0.210	0.060	VS	25.	MEDIUM	SLIGHT BROWN	63.60	VPOOR
# MOTORS IN LOT COMBO: 2	AVG AGE,MO: 150.50	LC AVG SHORE A: 65.08	3 SIGMA-SHORE A: 6.26											
LOT COMBO: 53. CTPB MFGR: GTR														
AA	21067.	160.00	0.080	0.000	STCKY	90	0.100	0.080	VSS	3.	LIGHT	NORM	66.70	VPOOR
# MOTORS IN LOT COMBO: 1	AVG AGE,MO: 160.00	LC AVG SHORE A: 66.70	3 SIGMA-SHORE A:											
LOT COMBO: 60. CTPB MFGR: GTR														
AA	21321.	122.00	0.120	0.040	VS	YES	0.220	0.100	VS	2.	MEDIUM	DARK GRAY	63.22	VPOOR

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 10 of 11

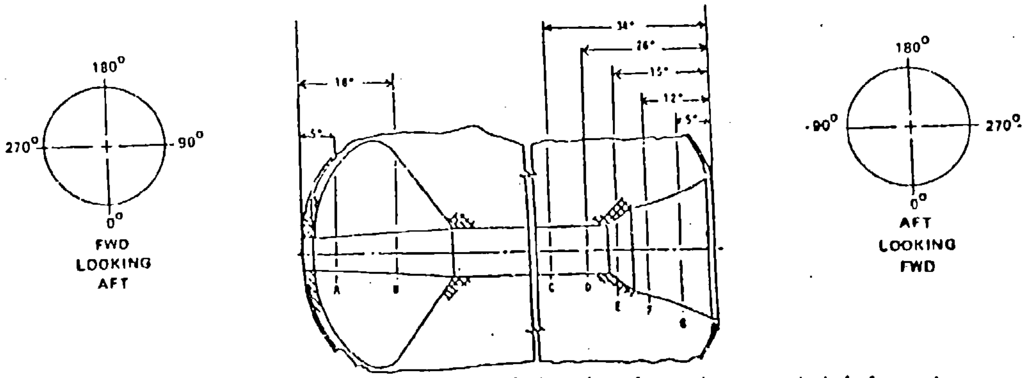
AA	STAGE2 SN	MOTOR AGE MO	FWD GAP 0	FWD LIFTING 0	FWD LINER	FWD UNBONDS	AFT GAP 180	AFT LIFTING 180	AFT LINER	AFT VOIDS QUANTITY	AP FWD	DISCOLORATION	SHORE A AVG	MOTOR CONDITION
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 122.00		LC AVG SHORE A: 63.22				3 SIGMA-SHORE A:		
LOT COMBO: 64.				CTPB MFGR: PHILLIPS										
AA	21434.	122.00	0.100	0.000	STCKY	90	0.050	0.000	SS	4.	LIGHT	NORM	71.10	VPOOR
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 122.00		LC AVG SHORE A: 71.10				3 SIGMA-SHORE A:		
LOT COMBO: 67.				CTPB MFGR: PHILLIPS										
AA	21480.	111.00	0.000	0.000	NORM	ND	0.000	0.000	NORM	4.	NONE	NONE	74.20	FAIR
# MOTORS IN LOT COMBO: 1						AVG AGE,MO: 111.00		LC AVG SHORE A: 74.20				3 SIGMA-SHORE A:		

		PHILLIPS MOTORS	GTR MOTORS
COUNT		111	132
MOTOR CONDITION:	FAIR	47	64
	POOR	49	42
	VPOOR	15	26

Figure A-9. Wash Out Motor Visual Inspection Report, Sheet 11 of 11

Motor SN: 1984 A (MSEX-2) Cast Date: September 1983 CTPB Vendor: Phillips

Test Date: 4 September 1985 Bay Temp: 82°F Age at Test: 24 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	51.3	60.5	68.3	68.0	73.0	71.8	73.3
On-Surface (K_{77})	45.4	44.2	44.8	49.5	51.6	46.6	51.2
- E_o (psi)	1217	1192.8	1198.6	1345	1411.8	1254.1	1399
- σ_m (psi)	105.1	104.1	104.6	108.7	110.5	106.2	110.2
- ϵ_m (%)	15.8	16.2	16.0	14.8	14.3	15.5	14.4
- ϵ_b (%)	21.8	22.3	22.0	20.2	19.4	21.3	19.6
Temperature (°F)	79.5	79.5	80.5	80.5	80.5	81.8	81.7

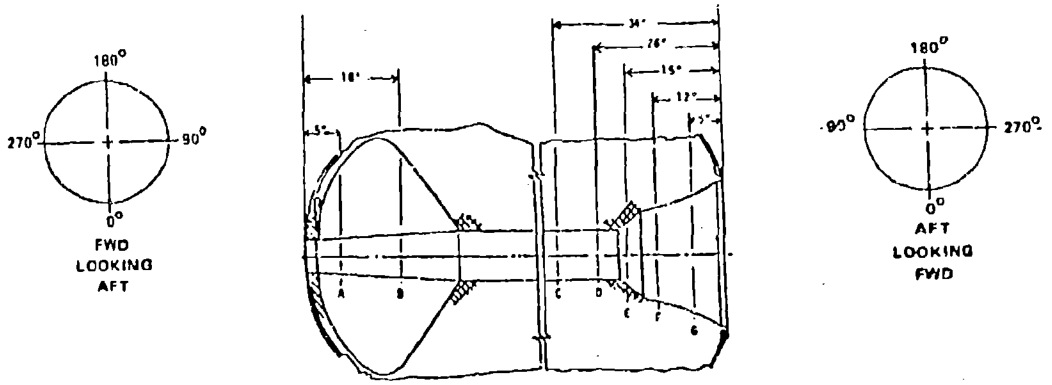
Visual Observations

1. Forward Bondline — No discrepancies.
2. Aft Bondline — No discrepancies.
3. Forward Bore — Fin material in 60°, 180°, 240° fin slots. Sand on propellant surface. Ignition delay samples were taken.
4. Cylindrical Bore — Bore samples removed at 0° and 270°.
5. Aft Nozzle Well — Voids: Numerous small voids at 210°, 7" in. 1/6" - 1/8" at 270° 7" in. Sand on propellant surface. Excise sample removed.
6. Other — Light dusting of oxidizer throughout.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 1 of 9

Motor SN: AA 20887 Cast Date: 23 June 1971 CTPB Vendor: Phillips

Test Date: 11 September 1985 Bay Temp (°F): 70 Age at Test: 228 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	57	64	70	70	75	74	74
On-Surface (K_{77})	47.5	48.6	52.7	56.4	57.2	48.5	46.8
- E_o (psi)	1282.1	1316.5	1447.3	1568.3	1595	1313.4	1260.3
- σ_m (psi)	106.9	107.9	111.5	114.7	115.4	107.8	106.5
- ϵ_m (%)	15.3	15.0	14.1	13.3	13.1	15.1	15.5
- ϵ_b (%)	20.9	20.5	19.0	17.8	17.5	20.5	21.2
Temperature (°F)	72.3	73.5	74.3	73.3	74	73.5	74

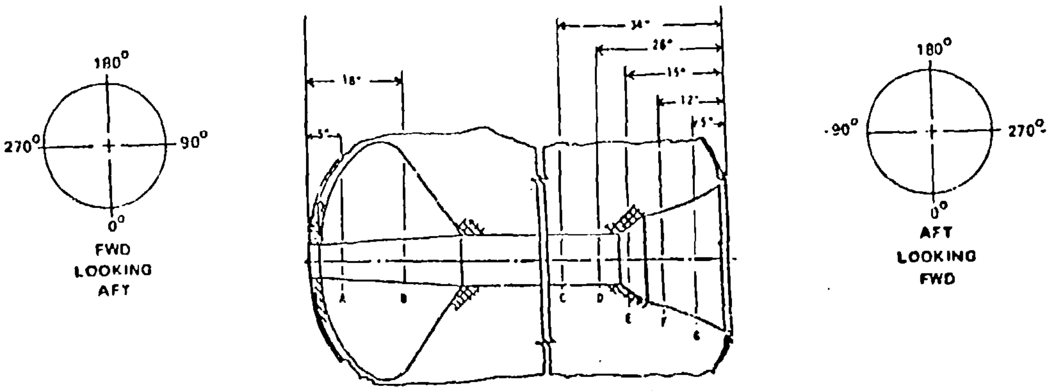
Visual Observations

1. Forward Bondline — Boot separation measurements 1/16" at 0°, 90°, 180°, 270°
2. Aft Bondline — Boot separation 1/16" at 0°, 90°; 5/32" at 180°; 1/8" at 270°.
3. Forward Bore — Moderate longitudinal scratches all fin rays; Gouges: 3/4" x 3/4" to 1-1/2" x 2" on fin rays
4. Cylindrical Bore — Brownish red discoloration.
5. Aft Nozzle Well — Void 1/8" at 310° 7-1/2" in. Gouges: 1/2" x 3/8" to 3/4" x 1" at 10°, 150°, 200°.
6. Other — Rough polymer surface on all fin slots. Light dusting of oxidizer throughout.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 2 of 5

Motor SN: AA 21434 Cast Date: 16 September 1975 CTPB Vendor: Phillips

Test Date: 20 November 1985 Bay Temp (°F): 78°F Age at Test: 121 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	52	62.8	67.3	68.8	72.8	70	71
On-Surface (K_{77})	44.2	47.2	49.2	51.8	56.5	49.1	44.4
- E_o (psi)	1180.2	1272.7	1335.4	1418.2	1571.7	1332.7	1186.3
- σ_m (psi)	104.1	106.7	108.5	110.7	114.8	108.4	103.8
- ϵ_m (%)	16.2	15.4	14.9	14.3	13.1	14.9	16.1
- ϵ_b (%)	22.3	21.0	20.3	19.3	17.7	20.3	22.2
Temperature (°F)	81	79.3	77.5	77.3	76.8	76.5	75.5

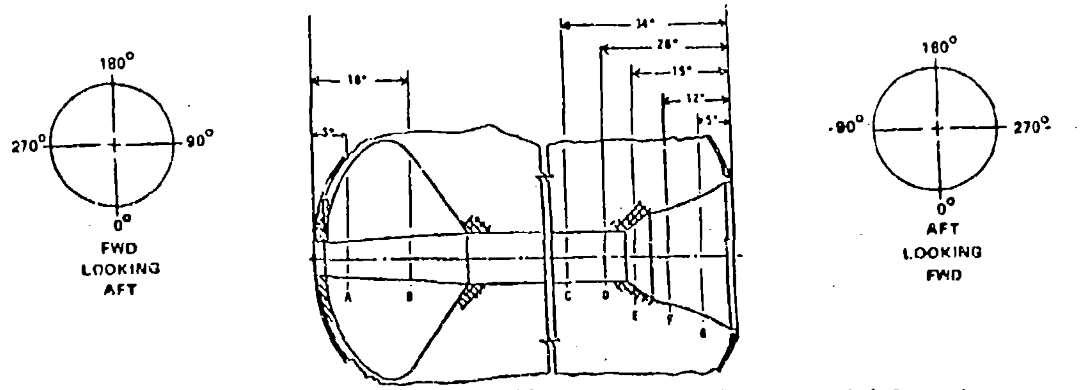
Visual Observations

1. Forward Bondline — Boot separation 3/32" to 3/16". Degraded liner present. Wrinkles in boot nipple. Boot shrinkage is evident.
2. Aft Bondline — Boot separation 5/32" to 3/16". Boot lifting 1/8" to 3/32".
3. Forward Bore — Patch of liner on fin ray at 330°. Propellant scraps on 30° fin ray. Fin material in 315° fin slot. Slump 1/8".
4. Cylindrical Bore — Small longitudinal scratches. Light dusting of oxidizer crystals.
5. Aft Nozzle Well — Voids: 1/4" x 3/16", 4" in 90°; 1/16", 1-1/2" in 250°; 3/16" x 5/16", 5-1/2" in 250°. Light dusting of oxidizer crystals.
6. Other — Brownish tint to propellant surface in nozzle well area.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 3 of 9

Motor SN: R7-036 (PQA 6-110) Cast Date: 23 November 1985 CTPB Vendor: Phillips

Test Date: 17 December 1985 Bay Temp (°F): 49 Age at Test: One (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	50	46	59	60	60	59	59
On-Surface (K_{77})	28.6	30	34	32.5	24.9	23.5	23.8
- E_o (psi)	730.9	769	880.5	838.3	632	595.4	603
- σ_m (psi)	90.5	91.7	124.8	93.9	87.3	86.1	86.3
- ϵ_m (%)	21.3	20.8	19.3	19.8	23.0	23.7	23.5
- ϵ_b (%)	30.3	29.4	27.1	27.9	32.8	33.9	33.7
Temperature (°F)	71.3	68.3	66.8	65	65.5	65	65.5

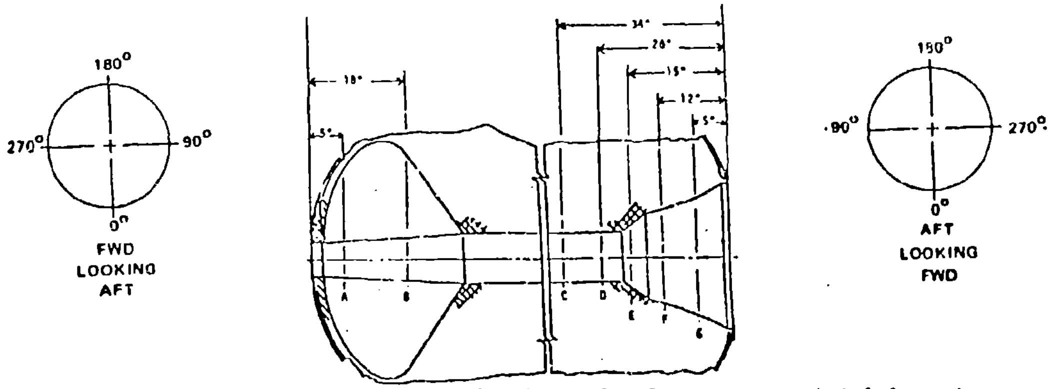
Visual Observations

1. Forward Bondline — No discrepancies.
2. Aft Bondline — No discrepancies.
3. Forward Bore — Few longitudinal scratches on all fin rays. Nonuniform polymer surface in all fin slots. Ignition delay samples taken.
4. Cylindrical Bore — Small bits of release agent throughout bore.
5. Aft Nozzle Well — Voids: 7/16 x 1/2 x 1/4, 290° 1" in.
   1/8 x 3/16, 270° 9" in.
6. Other

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 4 of 9

Motor SN: R7-038 Cast Date: 10 December 1985 CTPB Vendor: Phillips

Test Date: 13 January 1986 Bay Temp (°F): 75 Age at Test: One (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	52.5	54.5	60.5	62	62.3	63.5	63.3
On-Surface (K_{77})	27.1	27.1	41.5	39.8	36.8	34.7	34.3
- E_o (psi)	690.5	690.5	1098.7	1048.2	960.5	902.5	889
- σ_m (psi)	89.2	89.2	118.2	100.2	97.6	95.8	95.4
- ϵ_m (%)	22.0	22.0	16.9	17.4	18.3	19.0	19.2
- ϵ_b (%)	31.3	31.3	23.4	24.2	25.6	26.7	26.9
Temperature (°F)							

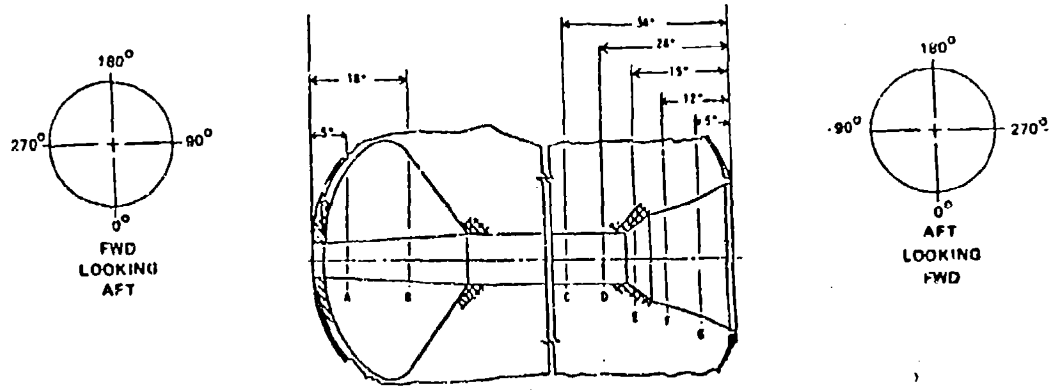
Visual Observations

1. Forward Bondline No visual observations were made on this motor.
2. Aft Bondline
3. Forward Bore
4. Cylindrical Bore
5. Aft Nozzle Well
6. Other

Figure A-10, Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 5 of 9

Motor SN: R8-003 Cast Date: 20 December 1985 CTPB Vendor: Phillips

Test Date: 22 January 1986 Bay Temp (°F): 80 Age at Test: One (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2	61	60.5	60.3	62	63.5	63.3	61
On-Surface (K_{77})	26.4	28.1	35.0	34.1	28	27.3	27
- E_o (psi)	671.8	718	909	883	715	696	688
- σ_m (psi)	89	90	96	95	90	89	89
- ϵ_m (%)	22	22	19	19	22	22	22
- ϵ_b (%)	32	31	27	27	31	31	31
Temperature (°F)	73.3	72.3	73.5	72.3	68.8	69.8	69.5

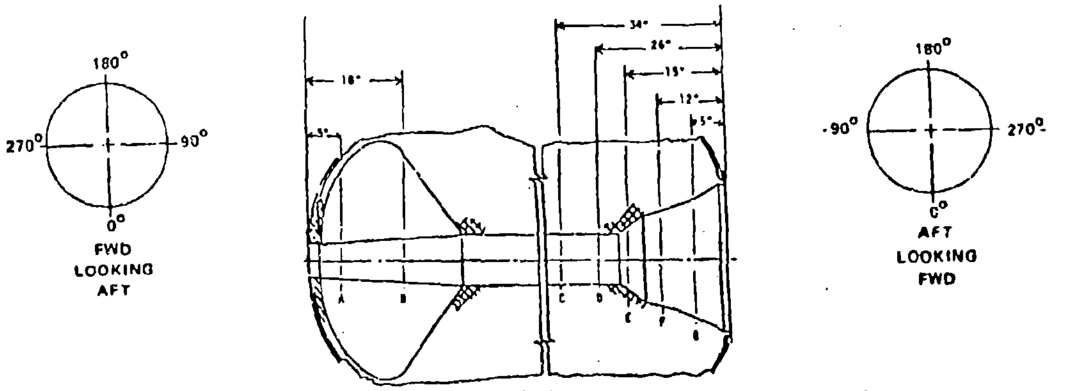
Visual Observations

1. Forward Bondline — No discrepancies.
2. Aft Bondline — No discrepancies.
3. Forward Bore — Few surface scratches on all fin rays. Some rough polymer surface in all fin slots.
4. Cylindrical Bore — No discrepancies.
5. Aft Nozzle Well — Voids: 0.3" x 0.35" x 0.3" 90° 1" in; 0.1 x 0.1 90° 9" in; 0.1" x 0.1" 270° 9" in.
6. Other — Light coating of propellant dust throughout motor bore.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 6 of 9

Motor S/N: R8-006 Cast Date: 27 January 1986 CTPB Vendor: Phillips

Test Date: 20 February 1986 Bay Temp (°F): 66 Age at Test: 21 Days



	Average of All Angular Locations at Axial Location:						
	A	B	C	D	E	F	G
Shore A2	52	55	58	53	57	56	54
On-Surface (K_{77})	26.4	270	32.2	29.0	26.8	25.3	25.3
- E_o (psi)	671.8	687.8	829.9	741.8	682.4	642.6	642.6
- σ_m (psi)	88.6	89.1	93.6	90.9	88.9	87.6	87.6
- ε_m (%)	22.3	22.0	19.9	21.2	22.1	22.8	22.8
- ε_b (%)	31.7	31.3	28.1	30	31.5	32.5	32.5
Temperature (°F)	64	64	64	65	66	66	65

Visual Observations

1. Forward Bondline — No discrepancies.

2. Aft Bondline — No discrepancies.

3. Forward Bore — Voids: 1/2" at 0° and 60° fin ray/bore interface.
Some rough polymer surface in all fin slots.
Scratch length of 150° fin ray.

4. Cylindrical Bore — No discrepancies.

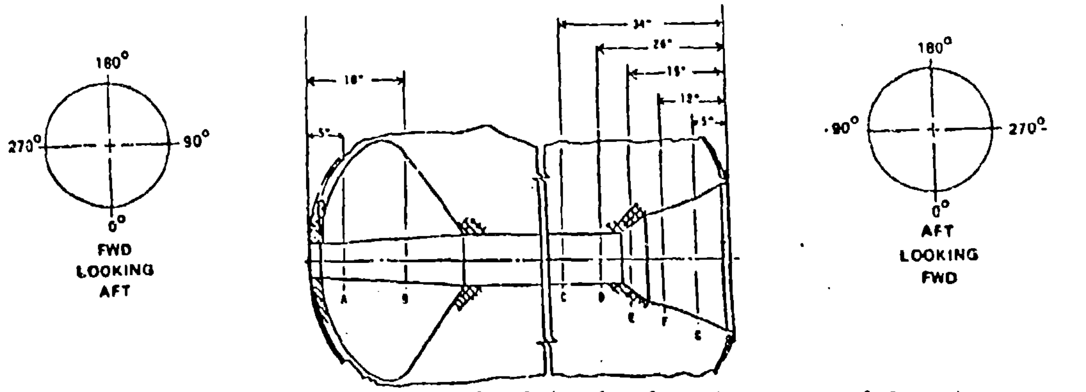
5. Aft Nozzle Well — Voids: 1/32", 0°, 1-1/2" in. 3/32" x 1/8", 30°, 7-1/2" in.
3/8" x 1/2", 45°, 1-1/2" in. 1/16", 340°, 7" in.

6. Other — None

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 7 of 9

Motor SN: AA 22114 (Hill) Cast Date: 14 March 1981 CTPB Vendor: Phillips

Test Date: 10 October 1985 Bay Temp (°F): ________ Age at Test: 54 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2							
On-Surface (K_{77})	56.3	46.1				57.6	52.7
- E_o (psi)	1521.1	1194.6				1564.3	1403.3
- σ_m (psi)	114.6	105.8				115.8	111.5
- ϵ_m (%)	13.3	15.7				13.0	14.2
- ϵ_b (%)	17.8	21.5				17.4	19.0
Temperature (°F)	77.3	77.3				69	69

Visual Observations

1. Forward Bondline

2. Aft Bondline

3. Forward Bore

4. Cylindrical Bore

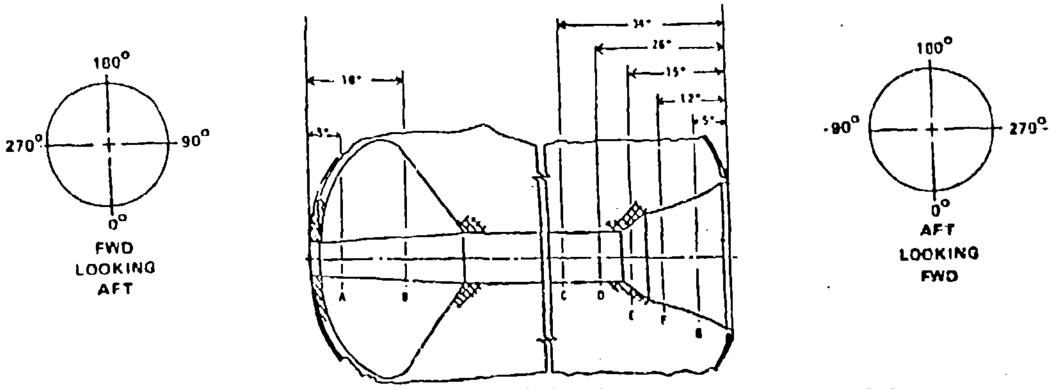
5. Aft Nozzle Well

6. Other On-Surface motor data from Hill AFB. No visual observations were provided.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 8 of 9

Motor SN: AA 22272 (Hill) Cast Date: 24 June 1983 CTPB Vendor: Phillips

Test Date: 6 November 1985 Bay Temp (°F): ______ Age at Test: 28 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2							
On-Surface (K_{77})	43.7	44.3				52.6	52.1
- E_o (psi)	1121	1139				1400	1383.9
- σ_m (psi)	103.7	104.2				111.4	111.0
- ϵ_m (%)	16.3	16.1				14.1	14.2
- ϵ_b (%)	22.5	22.2				19.1	19.2
Temperature (°F)	73.5	73.5				52.6	74.3

Visual Observations

1. Forward Bondline
2. Aft Bondline
3. Forward Bore
4. Cylindrical Bore
5. Aft Nozzle Well
6. Other On-Surface motor data from Hill AFB. No visual observations were provided.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Sheet 9 of 9

Ignitability Testing Summary for This Report Period

Motor AA-20887

IF = 697 psi/sec Predicted Ignition Delay = NA

The results of this test are considered anomalous since the IDM grain was over-conditioned (for 3 days) at 80%RH prior to firing (see discussion in Section VI. 4. c.). The quality of the excised samples is adequate. SEM indicated a typical surface.

Motor AA-21343

IF = 1961 psi/sec Predicted Ignition Delay = 0.121 sec

The data from this test indicates an 8% longer ignition delay time than normal and is consistent with the motor finocyl condition and SEM analysis. The quality of the excised sample is good.

Motor R7-017 (LC-89)

IF = 1273 psi/sec Predicted Ignition Delay = 0.134 sec

The data from this test indicates a 24% longer ignition delay than normal. The IDM data <u>is not</u> consistent with observed finocyl surface condition or SEM analysis. Low performance may be attributed to the poor quality of the excised sample surface and/or subsequent exposure to 80%RH prior to firing.

Motor R8-006 (LC 90)

IF = 2265 psi/sec Predicted Ignition Delay = 0.105 sec

Figure A-11. Ignitability Testing for This Report Period, Sheet 1 of 2

The data from this test indicates a normal ignition delay and is consistent with finocyl surface condition and SEM analysis. This motor is the first regrain to incorporate processing changes designed to eliminate the core roughness in the upper fin slot. This IDM grain was not conditioned at 80%RH prior to firing.

Motor R7-014 (PQA 6-109)

IF = 2635 psi/sec   Predicted Ignition Delay = 0.099 sec.

This motor was reported in SAAS-35 but the SEM analysis had not been completed. Previously reported data is consistent with SEM data and a prefire report was issued on 10 October, 1985.

Motor R7-036 (PQA 6-110)

IF = 1201 psi/sec   Predicted Ignition Delay = 0.136 sec

Test results from this motor are considered anomalous as the performance is not consistent with the sample condition or SEM data. The surface of the excised propellant is very rough (due to core roughness). This IDM was conditioned at 80%RH prior to firing. A prefire report was issued on 29 January 1986.

Motor R8-003 (PQA 6-111)

IF = 2408 psi/sec   Predicted Ignition Delay = 0.104 sec.

Test results from this motor indicate a normal ignition and are consistent with the finocyl condition and SEM analysis. The excised samples were somewhat rough but this IDM was not subject to high RH prior to firing. A prefire report is pending.

Figure A-11. Ignitability Testing for This Report Period, Sheet 2 of 2

Motor No.	Age (Mos)	CTPB	PREDICTION	ACTUAL(1)	% ERROR	REMARKS (VISUAL AND SEM)
AA 20011	197	GTR	0.116	NA	-	Rough Surface - No Crystals
AA 20026 (OP-59)	206	GTR	0.142	0.102	39	No Crystels-Mostly Smooth-Slight Reddish Color
AA 20033 (OP-58)	203	GTR	0.113	0.106	24	Relatively Smooth Surface-Some Small Crystals and Degradation
AA 20043 (OP-60)	209	GTR	0.113	0.126	101	Light Covering of Small Crystals Observed at Hill AFB. None Observed on Samples Used for Testing.
AA 20045 (OP-57)	197	GTR	0.111	0.115	3	Relatively Smooth Surface - No Crystals
AA 20051 (OP-56)	192	GTR	0.112	0.098	14	Some Gouges & Small Crystals-Generally Rough Surfece
AA 20053	180	GTR	0.081	NA	-	Normal Appearing with Scrape Marks
AA 20074 (OP-61)	210	GTR	0.114	0.097	18	Some Surface AP Crystals-Early Signs of Degradation
AA 20077	181	GTR	0.104	NA	-	Normal Appearing
AA 20083	181	GTR	0.095	NA	0	Reddish Color to Surface-Degraded Polymer
AA 20086	180	GTR	0.092	NA	0	Very Fine Layer of Crystals Over Surface
AA 20094 (OP-53)	179	Phillips	0.105	0.106	1	Some Surfaces with Degraded Polymer
AA 20095 (OP-62)	199	Phillips	0.074	0.101	29%	Small Amount of Red Coloring-Sample Damaged by Excising
AA 20100	180	Phillips	0.108	NA	-	Reddish Color to Surface-Degraded Polymer
AA 20101 (OP-63)	216	Phillips	0.114	0.094	20	Reddish, Rough with Sticky Brown Surface
AA 20143	216	Phillips	0.120	NA	-	Rough Texture
AA 20145	179	Phillips	0.113	NA	-	Normal Appearing-Some Rough Spots on Surface
AA 20167 (OP-55)	183	Phillips	0.101	0.096	5	Normal Surface-Some Rough Spots
AA 20177	177	Phillips	0.086	NA	-	Some Surface With Degraded Polymer
AA 20216	177	GTR	0.130	NA	-	Very Degraded Surface with Crystals
AA 20226	178	Phillips	0.106	NA	-	Smooth Dull Surface-Normal Brownish Color

Figure A-12. Summary of Ignition Delay Testing Conducted on Propellant Removed from Stage II Motors, Sheet 1 of 4

Motor No.	Age (Mos)	CTPB	PREDICTION	ACTUAL(1)	% ERROR	REMARKS (VISUAL AND SEM)
R3-030 (PQA 6-96)	0	Phillips	0.113	0.111	2	No Crystals-Mostly Rough Surfaces (Poor Release)
R3-042 (LC-80A)	0	Phillips	0.107	NA	-	No Crystals-Mostly Rough Surfaces
R3-062 (PQA 6-98)	0	Phillips	0.097	0.102	5	No Crystals-Mostly Rough Surfaces (Poor Release)
R4-009 (LC-81)	0	Phillips	0.102	NA	-	No Crystals-Mostly Smooth-Slightly Greenish Color
R4-022 (PQA 6-99)	0	Phillips	0.107	0.100	7	Normal Appearing-Slightly Rough-Possibly Damaged During Excising
R4-036 (LC-82)	0	Phillips	0.126	NA	-	Orange Peel Surface-Not Degraded
R4-037 (PQA 6-100)	0	Phillips	0.112	0.102	10	Rough Surface-Possibly Damaged During Excise
R4-052 (LC-83)	0	Phillips	0.107	NA	-	Some Debris-Not Degraded
R4-061 (LC-83)	0	Phillips	0.121 (3)	NA	-	
R4-065 (PQA 6-101)	0	Phillips	0.1119	0.100	19%	Few Tiny Green Specks
R5-008 (PQA 6-102)	0	Phillips	0.115	NA	-	Few Green Particles on Surface
R5-027 (PQA-103)	0	Phillips	0.122	NA	-	No Release and No Discoloration
R6-002	0	Phillips	0.133	NA	-	None
R6-018 (LC-86A)	0	Phillips	0.158	NA	-	Indentations and Scratches
R6-005 PQA 6-105	0	Phillips	0.071	0.097	27%	White Powdery Surface
R5-043A (PQA 6-106)	0	Phillips	0.117	0.101	14	White Powder; Rough Surface
R6-051	0	Phillips	0.099	0.107	0	Rough Surface; Embedded Styrofoam
R6-049 (LC-87)	0	Phillips	0.101	NA	-	Rough, Pitted Surface
R6-072 (LC-88)	0	Phillips	0.128	NA	-	Rough, Atypical of Finocyl
R6-069 (PQA 6-108)	0	Phillips	0.127	0.100	22%	Poor Ignition; Samples Atypical of Finocyl
R7-014 (PQA 6-109)	0	Phillips	0.099	Pending	-	Rough; Atypical of Finocyl
Plugged Motors						
AA 21480	110	Phillips	0.113	NA	-	Normal, Tested 7/85
MSEX-2 (1984A)	0	Phillips	0.125	NA	-	Rough Texture, Shiny Finish, Tested 12/85

Figure A-12. Summary of Ignition Delay Testing Conducted on Propellant Removed from Stage II Motors, Sheet 2 of 4

Motor No.	Age (Mos)	CTPB	PREDICTION	ACTUAL(1)	% ERROR	REMARKS (VISUAL AND SEM)
AA 20261	171	Phillips	0.098	NA	-	Surface Polymer Layer Slightly Degraded
AA 20263	176	Phillips	0.100	NA	-	Normal Appearing-Some Small Crystals
AA 20288	182	Phillips	0.106	NA	-	Shiny (Glassy) Surface-No Crystals
AA 20301	190	Phillips	0.127	NA	-	No Crystals
AA 20369	197	GTR	0.118	NA	-	Light Gray in Color
AA 20415		GTR	0.150	NA	-	Reddish Color-Relatively Smooth
AA 20419	203	GTR	0.118	NA	-	Normal Surface-Few Crystals
AA 20436	176	GTR	0.125	NA	-	Few Scattered Crystals
AA 20442	192	GTR	0.111	NA	-	Large Amount of Crystal Formation
AA 20473	195	GTR	(Inadequate to Test Samples)			Grayish White with Fine Crystals Over 70% of Surface
AA 20479	176	GTR	0.110	NA	-	Some Small Crystals in Isolated Spot
AA 20488	192	GTR	0.122	NA	-	Light Gray with Powdery Texture
AA 20559	81	GTR	0.118	NA	-	15% Red Discoloration
AA 20579	166	GTR	0.117	NA	-	Slightly Rough with Some Reddish Color
AA 20617	160	GTR	0.110	NA	-	Reddish Color-Crystals on All Surfaces and Rough
AA 20637	160	GTR	0.124	NA	-	Some Small Oxidizer Crystals-Reddish Color
AA 20106	222	Phillips	0.067	NA	-	Reddish Discoloration and Scuffing
AA 20114	221	Phillips	0.114	NA	-	Reddish Discoloration-Scuffing/Crosshatch
AA 20495	200	GTR	0.102	NA	-	None
AA 20149	138	GTR	0.119	NA	-	None
AA 20596	193	GTR	0.110	NA	-	Excessive AP on Pinocyl Surfaces
			0.127			Visually Observed; Surface of Samples was
			0.117			Scrubbed by Excise Tooling
AA 20613	208	Phillips	0.107	NA	-	Rough Surface; AP
AA 20530	203	GTR	0.108	NA	-	Rough, Pitted Surface
AA 20402	217	GTR	0.132	NA	-	Free Crystals on Surface
AA 20529	197	Phillips	Bad Firing	NA	-	Over Conditioned at High RH
AA 21321	132	GTR	0.122	NA	-	Rough, Pitted Patches on Surface
R2-017 (PQA 6-92)	0	Phillips	0.102	0.103	1	One Surface with Pool Release
R2-033 (PQA 6-93)	0	Phillips	0.095	0.100	5	Normal Appearing-Slightly Disrupted Polymer
R2-036 (LC-77)	0	Phillips	0.095	NA	-	Normal Appearing-Slightly Rough Surfaces
R2-039 (PQA 6-94)	0	Phillips	0.115	0.106	8	Normal Appearing
R2-054 (LC-78)	0	Phillips	0.092	0.100	8	Rough Surface-Poor Release and No Crystals
R3-007 (PQA 6-95)	0	Phillips	0.106	0.103	3	Normal-Smooth
R3-013 (LC-79)	0	Phillips	(2)	NA	-	Rough-Poor Release, No Crystals

Figure A-12. Summary of Ignition Delay Testing Conducted on Propellant Removed from Stage II Motors, Sheet 3 of 4

Motor No.	Age (Mos)	CTPB	PREDICTION	ACTUAL(1)	% ERROR	REMARKS (VISUAL AND SEM)
The following motors were tested this report period.						
AA 20887	228	Phillips	Bad Firing	NA	-	Overconditioned (72 Hrs vs 24) at 80%RH
AA 21343	121	Phillips	0.121	NA	-	Poor Samples; Covered with Cutting Debris
R7-017 (LC-89)	0	Phillips	0.134	NA	-	Poor Ignition; Samples Atypical of Finocyl
R8-006 (LC-90)	0	Phillips	0.108	NA	-	Normal; Good Samples
R7-036 (PQA 6-110)	0	Phillips	0.136	Pending	-	Test Results Considered Anomalous
R8-003 (PQA 6-111)	0	Phillips	0.104	Pending	-	Normal Ignition Expected
MSEX-2 (Plugged Motor)	24	Phillips	0.134	NA	-	Shiny Surface, Pitted
MSEX-2 Analog	24	Phillips	0.125	NA	-	Reddish Discoloration

Figure A-12. Summary of Ignition Delay Testing Conducted on Propellant Removed from Stage II Motors, Sheet 4 of 4

Appendix B

Materials From Lab Samples

Lot Comb	Storage		Test Temperature																								
			0°F					40°F					77°F					110°F					150°F*				
	Time, Month	Temp, °F	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA
85A	0																										
	Control	80	164	23	41	1608	45	109	29	48	643	44	90	33	46	396	48	74	34	50	299	45	61	18	19	342	50
	12	80																									
	16	110																									
	8	135	230	16	24	2698	66	172	18	24	1523	65	137	21	26	923	68	117	20	24	791	61	66	17	17	414	64
85B	0												89	35	56	410											
	Control		160	24	43	1432	46	114	27	42	780	44	83	31	44	421	45	74	30	41	382	46	54	26	27	206	46
	12	80	244	21	32	2383	56	178	25	34	1215	53	108	27	38	560	55	99	28	38	503	53	57	20	21	275	-
	16	110	238	17	26	2406	64	176	19	24	1552	66	136	21	25	975	64	119	20	24	867	68	61	18	18	379	63
	8	135	249	16	25	2694	62	175	19	24	1434	64	144	20	25	1038	64	123	21	26	837	61	67	16	17	428	63
86	Control		177	21	41	1601	45	110	28	44	707	47	94	30	40	440	46	80	32	43	344	46	63	20	20	328	52
	8	135	252	16	21	2802	66	179	18	22	1693	65	149	20	25	1076	67	128	20	23	918	66	75	17	17	478	66
65A	0												93	36	55	532											
	Control		212	20	38	2095	52	159	24	36	1132	55	107	29	44	521	53	91	28	42	474	54	61	24	24	269	
	12	80	231	19	29	2478	63	176	21	28	1472	64	123	27	36	657	60	108	27	34	563	64	62	22	23	259	58
	16	110	258	16	24	2971	67	187	18	22	1787	65	150	20	25	1142	67	132	20	24	1000	66	71	15	16	498	66
	8	135	258	16	21	2786	71	183	18	22	1565	7C	156	19	22	1225	67	130	17	20	1072	70	71	15	15	502	68
87B	0												110	36	51	523											
	Control		197	20	41	1987	55	136	25	42	911	57	107	27	41	591	53	94	28	38	488	55	59	15	15	466	60
	12	80	227	19	27	2313	59	160	24	31	1177	59	126	25	32	810	59	114	22	29	787	59	60	18	19	333	-
	16	110	291	14	18	3350	63	222	16	19	2165	63	162	19	21	1227	62	136	18	20	1034	63	75	14	14	574	63
	8	135	276	15	22	3600	68	191	17	22	1880	68	154	17	19	1324	69	131	16	16	1098	67	65	11	12	624	67
88D	0												95	33	52	503											
	Control		174	24	49	1656	48	114	30	51	586	48	86	33	51	385	50	72	35	53	285	50	60	25	26	246	-
	12	80																									
	16	110																									
	8	135	250	17	26	2480	65	188	20	26	1416	61	147	21	25	977	64	143	19	21	967	63	75	16	16	472	63
89	0												81	35	56	387											
	Control		176	22	47	1803	51	122	28	46	710	51	96	31	48	448	51	81	33	46	351	53	57	25	26	226	52

* Strain Rate: 0.0074 min^{-1}, all other temperatures at 0.74 min^{-1}

Figure B-1. Comparison of Uniaxial Tensile Properties from the Bulk of ANB-3066 Propellant

Test Temperature: 77°F
Strain Rate: 100 min^{-1}
Superimposed Pressure: 600 psig

Lot Combo	Storage Time, mo	Storage Temp, °F	σ_m, psi	ϵ_m, %	ϵ_b, %	E_o, psi	SA
85A	Control		324	47	58	907	44
	8	135	430	31	33	2394	67
85B	Control		317	49	58	1161	44
	12	80	375	43	47	1419	56
	16	110	444	36	38	1939	64
	8	135	456	34	34	2339	64
86	Control		303	49	62	1131	44
	8	135	429	30	32	2467	67
86A	Control		391	44	51	1494	54
	12	80	450	44	46	1865	64
	16	110	471	32	32	2671	63
	8	135	461	31	33	2503	68
87B	Control		376	44	54	1467	54
	12	80	415	39	41	2038	58
	16	110	498	30	32	2773	64
	8	135	469	31	31	2680	64
88D	Control		320	48	60	1228	50
	12	80					
	16	110					
	8	135	459	35	36	2228	61
89A	Control		352	51	61	1521	52
	12	80					
	16	110					
	8	135					

Figure B-2. Effect of Storage Conditions and High Rate on Uniaxial on Uniaxial Tensile Properties of ANB-3066 Propellant

Applied Strain:: 2%

Test Temperature

Lot Comb	Storage Time, Month	Storage Temp, °F	0°F Relaxation Mod., Time 0.1	0°F 1.0	0°F 10.0	40°F Relaxation Mod., Time 0.1	40°F 1.0	40°F 10.0	77°F Relaxation Mod., Time 0.1	77°F 1.0	77°F 10.0	110°F Relaxation Mod., Time 0.1	110°F 1.0	110°F 10.0	150°F Relaxation Mod., Time 0.1	150°F 1.0	150°F 10.0
85A	Control	80	1696	817	479	-	-	-	457	286	222	-	-	-	339	256	196
	12	80															
	16	110															
	8	135	2973	1778	1223	-	-	-	1020	735	594	-	-	-	645	507	408
85B	Control	80	1646	772	448	-	-	-	438	277	216	-	-	-	245	182	143
	12	80	1927	1020	642	-	-	-	490	322	253	-	-	-	321	243	192
	16	110	3167	1846	1248	-	-	-	958	675	539	-	-	-	621	492	401
	8	135	3177	1886	1284	-	-	-	1076	750	603	-	-	-	685	538	439
86	Control	80	1652	800	472				450	279	215	413	284	222	409	304	235
	8	135	3603	2184	1540	-	-	-	1170	838	682	-	-	-	577	533	438
86A	Control	80	2245	1204	753	-	-	-	600	379	292	-	-	-	301	229	182
	12	80	2933	1660	1077	-	-	-	845	564	446	-	-	-	448	342	275
	16	110	3446	2105	1440	-	-	-	1356	946	757	-	-	-	877	689	561
	8	135	3462	2158	1521	-	-	-	1265	928	760	-	-	-	956	734	606
87B	Control	-	2061	1076	698	-	-	-	539	349	271	379	275	220	-	-	-
	12	80	3345	1978	1343	-	-	-	963	656	520	-	-	-	507	392	317
	16	110	4342	2778	1968	-	-	-	1590	1145	925	-	-	-	1073	827	677
	8	135	4178	2619	1868	-	-	-	1641	1185	963	-	-	-	1186	930	768
88D	Control		1646	746	459	-	-	-	352	220	171	-	-	-	224	164	127
	12	80															
	16	110															
	8	135	3282	1921	1278	-	-	-	1232	875	703	-	-	-	772	605	486
89	Control		2014	972	593	-	-	-	441	267	202	-	-	-	252	187	144

* Applied Strain 0.5%

Figure B-3. Effect of Test Temperature on Relaxation Modulus for ANB-3066 Propellant: Different Lot Combination

			0.1 in. from Bore				0.2 in. from Bore				0.5 in. from Bore				1.0 in. from Bore				2.0 in. from Bore			
Lot Comb	Time, Month	Temp, °F	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	σ_m, psi	ε_m, %	ε_b, %	E_o, psi
85A	Control	80	107	24	34	670	100	25	38	595	97	27	42	525	94	29	40	450	93	31	44	427
	12																					
	16	110																				
	8	135	173	10	11	2201	177	11	13	2166	160	14	16	1476	132	21	29	900	132	19	24	946
85B	Control	80	98	25	34	579	95	24	35	552	82	28	41	441	77	29	44	389	75	32	45	326
	12	80	129	18	28	1002	129	19	28	950	132	20	26	923	122	24	31	754	101	27	38	541
	16	110	159	13	15	1682	157	13	17	1674	147	15	18	1370	113	25	35	691	120	22	28	793
	8	135	194	10	11	2712	190	10	12	2580	150	16	20	1340	133	21	30	1023	132	19	25	956
86	Control	80	116	24	32	758	107	24	32	657	97	27	38	537	94	29	40	488	92	31	43	443
	8	135	186	10	10	2536	182	10	11	2365	161	14	16	1514	134	20	27	937	142	19	24	996
86A	Control	80	128	19	29	1332	120	19	29	1120	109	22	31	904	99	25	40	699	98	26	38	580
	12	80	137	19	27	1065	137	19	25	1087	147	17	23	1233	139	20	25	1094	122	23	32	795
	16	110	178	12	14	2089	168	13	16	1827	159	14	17	1570	125	25	34	847	135	20	24	1008
	8	135	196	10	11	2666	190	10	11	2680	154	16	18	1388	139	20	25	1069	149	19	22	1171
87B	Control		138	17	27	1247	132	18	27	1166	115	20	34	905	98	25	38	631	99	25	37	623
	12	80	144	16	23	1361	142	16	22	1238	143	17	22	1170	128	21	28	950	119	22	31	874
	16	110	156	9	9	2143	174	11	13	2068	173	12	14	1972	145	20	26	1022	150	18	23	1096
	8	135	203	8	8	3283	201	8	10	3154	166	15	18	1670	150	19	24	1247	156	16	19	1502
88D	Control		106	21	36	796	100	22	36	723	90	26	41	553	86	26	40	495	88	27	45	437
	12	80																				
	16	110																				
	8	135	180	11	12	2164	178	12	14	2082	154	18	19	1306	136	20	27	969	142	18	24	1058
89	Control		99	20	37	900	100	24	37	828	96	24	37	746	91	26	41	614	90	27	43	482

Figure B-4. Comparison of Uniaxial Tensile Gradient from the Simulated Bore Surface of Analog Samples of ANB-3066 Propellant (Sealed Samples)

Test Temp: 77°F
Applied Strain: 2.0%

Lot Comb	Storage Time, Month	Storage Temp, °F	0.1 in. from Bond Relaxation Mod., Time 0.1	1.0	10.0	0.2 in. from Bond Relaxation Mod., Time 0.1	1.0	10.0	0.5 in. from Bond Relaxation Mod., Time 0.1	1.0	10.0	1.0 in. from Bond Relaxation Mod., Time 0.1	1.0	10.0	2.0 in. from Bond Relaxation Mod., Time 0.1	1.0	10.0
85A	Control	80	2686	1778	1363	1360	839	638	751	469	375	783	490	381	775	489	382
	8	135	1046	706	550	2530	1768	1382	1295	846	662	863	519	401	1042	672	526
85B	Control	80	929	644	522	940	576	442	590	368	287	649	405	316	658	411	320
	12	80	1333	975	762	1545	1003	771	1102	708	562	756	471	377	590	385	313
	16	110	708	517	418	2061	1426	1119	1832	1282	1028	960	612	482	1032	680	540*
	8	135	962	650	522	2414	1759	1386	879	559	430	904	593	466	1116	758	608
86	Control	80	1380	947	726	1271	777	575	900	539	422	779	476	360	826	507	392
	8	135	1408	997	797	2841	2020	1572	1288	842	668	1243	788	617	1444	982	790
86A	Control	80	1268	846	679	1321	815	628	735	455	357	809	507	392	809	504	387*
	12	80	2536	1767	1400	2130	1379	1168	1494	973	776	1280	815	656	982	645	515
	16	110	1772	1229	972	2351	1590	1238	2102	1444	1142	1298	803	614	1358	925	741
	8	135	1608	1140	911	2424	1736	1374	1218	764	594	1330	888	702	-	-	-
87B	Control	80	2750	1931	1524	2060	1312	999	2185	728	549	1200	744	574	1094	677	515
	12	80	3015	2169	1698	2436	1656	1304	1997	1370	1102	1722	1115	856	1535	1040	834
	16	110	1760	1239	994	3260	2261	1780	2809	1970	1536	1726	1093	844	2130	1455	1138
	8	135	2119	1523	1248	3883	2752	2232	1952	1234	951	1972	1303	1040	2298	1592	1278
88D	Control		2265	1505	1168	1152	727	574	628	390	314	578	362	291	625	388	302*
	12	80															
	16	110															
	8	135	2028	1465	1177	3488	2450	1952	1360	867	688	1399	917	718	1646	1114	898
89	Control		2358	1554	1185	1495	892	652	985	593	455	894	535	410	885	526	402*

* 1.5 in. from bond interface.

Figure B-5. Comparison of Mini Stress Relaxation Modulus from the Simulated Bond Surface of Analog Samples of ANB-3066 Propellant

			Standard				Mini			
Type Specimen →			Standard				Mini			
Test Temperature, °F →			77				77			
Crosshead Rate, in./min →			1.0				0.5			
					Type Failure, %				Type Failure, %	
Lot Combo	Time, mo	Temp, °F	Stress, psi	Time, min	APL	CL	Stress, psi	Time min	APL	CL
85A	*0		84.7							
	Control		93	0.13	90	10	96	0.16	100	
	8	135	74	0.38	95	5	64	0.49	95	5
85B	*0		84.7							
	Control		85	0.30	85	15	72	0.31	85	15
	12	80	78	0.21	60	40	71	0.26	65	35
	16	110	59	0.23	50	50	64	0.34	50	50
	8	135	63	0.24	80	20	58	0.27	65	35
86	*0		-							
	Control		94	0.15	90	10	80	0.17	95	5
	8	135	72	0.25	50	50	62	0.20	60	40
86A	*0		79.0							
	Control		99	0.23	100		100	0.08	100	
	12	80	107	0.17	97	3	84	0.21	96	4
	16	110	69	0.25	50	50	69	0.42	89	11
	8	135	71	0.25	90	10	80	0.52	80	20

* Liner lot qualification

Figure B-6. Effect of Storage Temperature and Time on Tensile Strength of Propellant-Liner-Insulation Bond System, Sheet 1 of 2

Type Specimen →			Standard					Mini			
Test Temperature, °F →			77					77			
Crosshead Rate, in./min →			1.0					0.5			
					Type Failure, %					Type Failure, %	
Lot Combo	Time, mo	Temp, °F	Stress, psi	Time, min	APL	CL	CLI	Stress, psi	Time min	APL	CL
87B	*0		89.3								
	Control		86	0.18	60	40		86	0.23	50	50
	12	80	109	0.29	60	40		102	0.19	60	40
	16	110	68	0.18	50	50		74	0.32	50	50
	8	135	88	0.22	70	30		88	0.30	70	30
88D	*0		89.3								
	Control		84	0.26	100			82	0.36	100	
	12	80									
	16	110									
	8	135	94	0.24	95	5		92	0.40	95	5
89	*0		70.0								
	Control		89	0.22		3	97	89	0.24	100	

* Liner lot qualification

Figure B-6. Effect of Storage Temperature and Time on Tensile Strength of Propellant-Liner-Insulation Bond System, Sheet 2 of 2

Test Temperatue: 77°F
Crosshead Rate: 200 in./min
Superimposed Pressure: 600 psig

Lot Combo	Storage Time, mo	Storage Temp, °F	Stress, psi	Time to Fail, sec	Type Failure, % CP	CPI	APL	CLI	CL	ALI	F
85A	Control		220	0.102			10		90		
	8	135	243	0.122			30		70		
85B	Control		241	0.120			70		30		
	12	80	208	0.105			50		50		
	16	110	172	0.055			50		50		
	8	135	–	–			–		–		
86	Control		250	0.113			50		50		
	8	135	282	0.107			100				
86A	Control		272	0.140			60		40		
	12	80	222	0.084			30		70		
	16	110	234	0.086			100				
	8	135	170	0.112			25		75		
87B	Control		253	0.160			50		40	10	
	12	80	216	0.091			50		50		
	16	110									
	8	135	217	0.120			30		70		
88D	Control		253	0.114			60		40		
	12	80	205	0.125					100		
	16	110									
	8	135									
89	Control		254	0.102			50	50			
	12	80									
	16	110									
	8	135									

Figure B-7. Effect of Storage Conditions on Bond Shear Strength of Propellant-Liner-Insulation Bond System (ANB-3066/SD-851-2/V-45)

Lot Combo	Storage Time, Mos.	Storage Temp, °F	Stress, psi	Time, Min.	Type Failure, % APL	CP	CLI	CL	F	Stress, psi	Time, Min.	Type Failure, % APL	CP	CLI	CL	F	Stress, psi	Time, Min.	Type Failure, % APL	CP	CLI	CL	F	Stress, psi	Time, Min.	Type Failure, % APL	CP	CLI	CL	F
85A	Control	80	40	667	50			50		35	861	50			50		30	1610	20	40		40		25	13217	50			50	
	8	135	50	15						40	919						35	4040						30	53184		95		5	
85B	Control	80	50	3.0					100	45	10.4	90			10		30	549	50			50		25	8420	60			40	
	12	80	55	8.0	40			60		45	1026	70			30		40	6464	70			30		35	14661	50	50			
	16	110	40	6.8	50			50		35	62	30			70		30	954	40			60		25	17670	40			60	
	8	135	40	28	60			40		35	305	25			75		30	1192	20			80		28	2257	20			80	
86	Control	80	45	230	90			10		40	497	90			10		35	818	90			10		30	1990	70			30	
	8	135	40	44	70			30		35	1067	60			40		30	2691	70			30		27.5	182531					
86A	Control	80	55	11.3	60			40		50	83	90			10		45	137	75			25		40	313	60			40	
	12	80	50	96	40			60		45	111	60			40		40	678	60			40		35	2301	50			50	
	16	110	40	16	50			50		30	2107	100					25	41,346						20	>87119					
	8	135	45	6.9	50			50		40	93				100		35	3068				100		30	6181				100	
87B	Control	80	50	107	40			60		45	1032	40			60		40	4153	30			70		35	112531					
	12	80	60	36.4	85			15		50	588	50			50		40	16548	50			50		35	22686	50			50	
	16	110																												
	8	135	45	9.1	50			50		40	1090	70			30		35	111	40			60		30	3653	40			60	
88D	Control		50	22	60			40		45	136	25			75		40	282	50			50		35	950	40			60	
	12	80																												
	16	110																												
	8	135	50	7	70			30		45	183	70			30		40	280	80			20		35	5012				100	
89	Control																													

* Test Discontinued

Figure B-8. Comparison of Constant Load Bond Tensile Results from Analog Samples of ANB-3066 Propellant

Applied Strain: 2%

Lot Comb	Storage Time, Month	Storage Temp, °F	0°F Relaxation Mod., Time 0.1	0°F 1.0	0°F 10.0	77°F Relaxation Mod., Time 0.1	77°F 1.0	77°F 10.0	77°F* Relaxation Mod., Time 0.1	77°F* 1.0	77°F* 10.0	150°F Relaxation Mod., Time 0.1	150°F 1.0	150°F 10.0
85A	Control	80	3885	1668	1180	-	-	-	-	-	-	737	616	551
	8	135	6157	3964	3210	1691	1357	1190	-	-	-	1274	1070	949
85B	Control	80	6997	2749	1896	1071	847	729	-	-	-	695	582	527
	12	80	7022	3390	2493	1568	1253	1116	-	-	-	928	783	704
	16	110	12223	5016	3372	1840	1503	1314	-	-	-	1108	930	814
	8	135	15006	5196	3187	1846	1533	1344	-	-	-	1048	880	800
86	Control	80	5706	2331	1646	1268	990	851	-	-	-	767	612	541
	8	135	12902	4928	3126	2019	1656	1440	-	-	-	1513	1256	1130
86A	Control	80	6536	2899	2081	1490	1215	1061	-	-	-	907	762	680
	12	80	5532	2477	1853	2008	1656	1434	-	-	-	790	652	574
	16	110	7803	3470	2479	1747	1408	1216	-	-	-	1123	923	811
	8	135	6186	2952	2188	1779	1445	1267	-	-	-	910	701	621
87B	Control	80	8763	3618	2445	1351	1088	967	-	-	-	904	774	681
	12	80	7946	3436	2429	1558	1252	1086	-	-	-	963	822	735
	16	110	8533	3934	2848	1494	1214	1058	-	-	-	884	728	634
	8	135	11425	4673	2789	2170	1774	1561	-	-	-	1352	1120	988
88D	Control		10746	4287	2826	1552	1294	1158	-	-	-	1007	857	774
	12	80												
	16	110												
	8	135	12524	4936	3140	1934	1604	1435	-	-	-	1144	978	884
89	Control		6218	3166	2422	1459	1162	1040	-	-	-	906	776	712

* Applied Strain: 0.5%

Figure B-9. Effect of Test Temperature on Relaxation Modulus for Insulation from Analog Samples of ANB-3066 Propellant

LOT COMBO	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 IW	970/ 2850
85B #386	0.0	1.0720	0.081	0.230	1.199
	0.1	1.0787	0.075	0.211	1.188
	0.2	1.0462	0.080	0.218	1.194
	0.3	1.0181	0.090	0.189	1.011
	0.5	1.0599	0.081	0.199	1.077
	2.0	1.0740	0.088	0.234	1.201
86A #401	0.0	1.0141	0.060	0.170	1.162
	0.1	1.0175	0.055	0.152	1.157
	0.2	1.0839	0.059	0.151	1.155
	0.3	1.0026	0.060	0.152	1.160
	0.5	1.0627	0.061	0.151	1.127
	2.0	1.0008	0.055	0.149	1.183
87B #415	0.0	1.0842	0.062	0.148	1.176
	0.1	1.0710	0.067	0.148	1.153
	0.2	0.9839	0.069	0.144	1.174
	0.3	1.0056	0.070	0.147	1.165
	0.5	1.0440	0.076	0.156	1.156
	2.0	1.0204	0.077	0.157	1.159
88D #420	0.0	1.0416	0.079	0.176	1.204
	0.1	1.0576	0.070	0.155	1.093
	0.2	1.0514	0.044	0.160	1.159
	0.3	1.0731	0.058	0.161	1.068
	0.5	1.0424	0.060	0.178	1.170
	2.0	1.0066	0.062	0.177	1.134
89A #500	0.0	1.0737	0.071	0.192	1.079
	0.1	1.0411	0.066	0.195	1.046
	0.2	1.0654	0.067	0.206	1.043
	0.3	1.0517	0.069	0.182	1.055
	0.5	1.0340	0.072	0.258	1.085
	2.0	0.9950	0.072	0.193	1.110

Figure B-10. FTIR Transmission Spectra Data; Gradient from Bore of Analog Cartons, Sheet 1 of 4

LOT COMBO	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 IW	970/ 2850
85B	0.0	1.0572		0.171	1.040
#389	0.1	1.0692	0.064	0.155	1.012
	0.2	0.9936	0.060	0.154	1.027
	0.3	1.0108	0.061	0.151	1.013
	0.5	1.0307	0.061	0.147	1.007
	2.0	1.0550	0.070	0.159	1.012
86A	0.0	1.0308	0.062	0.171	1.086
#402	0.1	1.0248	0.057	0.140	1.014
	0.2	0.9948	0.056	0.143	1.000
	0.3	1.0551	0.056	0.145	0.994
	0.5	0.9581	0.058	0.141	0.964
	2.0	0.9273	0.059	0.170	1.060
87E	0.0	1.0020	0.055	0.133	1.137
#412	0.1	1.0190	0.051	0.127	1.132
	0.2	1.0279	0.050	0.118	1.142
	0.3	0.9995	0.049	0.116	1.149
	0.5	1.0310	0.052	0.118	1.130
	2.0	1.0247	0.056	0.132	1.107

Figure B-10. FTIR Transmission Spectra Data; Gradient from Bore of Analog Cartons, Sheet 2 of 4

LOT COMBO	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 IW	970/ 2850
85B	0.0	1.0809	0.041	0.128	1.045
#387	0.1	1.0977	0.041	0.122	0.950
	0.2	1.0423	0.039	0.130	1.000
	0.3	1.0722	0.017	0.118	0.962
	0.5	1.0572	0.035	0.131	1.037
	2.0	1.0629	0.063	0.159	1.030
86A	0.0	1.0223	.042	0.086	1.023
#401	0.1	1.0109	0.041	0.088	1.011
	0.2	1.0228	0.042	0.088	1.047
	0.3	0.9954	0.043	0.089	1.085
	0.5	1.0104	0.042	0.095	1.091
	2.0	1.0229	0.046	0.109	1.109
87B	0.0	0.9915	0.046	0.085	0.848
#411	0.1	1.0019	0.044	0.086	0.905
BORE	0.2	0.9770	0.042	0.082	0.872
	0.3	1.0062	0.043	0.084	0.904
	0.5	1.0001	0.045	0.091	0.919
	2.0	1.0083	0.048	0.107	0.973

Figure B-10. FTIR Transmission Spectra Data; Gradient from Bore of Analog Cartons, Sheet 3 of 4

LOT COMBO	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 IW	970/ 2850
85B	0.0	1.0128	0.056	0.100	0.981
#388	0.1	1.0688	0.058	0.094	1.000
	0.2	1.0528	0.057	0.091	1.011
	0.3	1.0689	0.057	0.093	0.990
	0.5	1.0450	0.059	0.158	1.138
	2.0	1.0238	0.063	0.131	1.055
86A	0.0	1.0955	0.041	0.079	0.860
#400	0.1	1.0935	0.038	0.075	0.882
	0.2	1.0576	0.040	0.078	0.828
	0.3	1.0174	0.040	0.077	0.796
	0.5	1.0767	0.047	0.115	0.984
	2.0	1.0648	0.046	0.101	0.956
373	0.0	1.0252	0.043	0.092	0.770
#413	0.1	0.9643	0.043	0.088	0.773
	0.2	1.0619	0.042	0.078	0.692
	0.3	1.0547	0.044	0.087	0.736
	0.5	1.0693	0.053	0.135	0.917
	2.0	1.0499	0.048	0.115	0.864
88D	0.0	1.0511	0.044	0.092	1.000
#422	0.1	1.0490	0.041	0.087	0.989
BORE	0.2	1.0430	0.040	0.088	1.000
	0.3	0.9804	0.041	0.088	0.977
	0.5	1.0419	0.051	0.129	1.089
	2.0	1.0332	0.048	0.119	1.070

Figure B-10. FTIR Transmission Spectra Data; Gradient from Bore of Analog Cartons, Sheet 4 of 4

ID#	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 WN	1295 WN	970/ 2850
85B	0.0	1.0207	0.066	0.143	0.047	0.986
#386	0.1	1.0765	0.086	0.207	0.045	1.205
	0.2	1.0462	0.091	0.230	0.050	1.176
	0.3	1.0164	0.094	0.187	0.022	1.000
	0.5	1.0942	0.085	0.224	0.038	1.184
	2.0	1.0340	0.094	0.225	0.040	1.165
86A	0.0	0.9099	0.048	0.158	0.014	1.125
#401	0.1	1.0085	0.057	0.136	0.019	1.142
	0.2	1.0465	0.055	0.136	0.017	1.092
	0.3	1.0297	0.061	0.142	0.016	1.123
	0.5	1.0495	0.058	0.142	0.014	1.088
	2.0	1.0314	0.058	0.146	0.017	1.135
87B	0.0	1.0684	0.069	0.117	0.041	1.068
#415	0.1	1.0631	0.063	0.134	0.025	1.224
	0.2	1.0505	0.083	0.143	0.019	1.163
	0.3	1.0762	0.070	0.144	0.017	1.192
	0.5	1.0847	0.086	0.151	0.018	1.197
	2.0	1.0724	0.081	0.151	0.021	1.157
88D	0.0	1.0518	0.043	0.087	0.034	1.227
#420	0.1	1.0316	0.051	0.150	0.032	1.240
	0.2	1.0449	0.055	0.160	0.030	1.160
	0.3	1.0786	0.058	0.159	0.025	1.103
	0.5	1.0512	0.061	0.176	0.027	1.108
	2.0	1.0312	0.059	0.167	0.028	1.162
89A	0.0	1.0739	0.049	0.092	0.028	1.000
#500	0.1	1.0398	0.059	0.169	0.034	1.121
	0.2	1.0150	0.065	0.177	0.032	1.065
	0.3	1.0365	0.066	0.182	0.029	1.080
	0.5	1.0652	0.072	0.190	0.028	1.098
	2.0	1.0179	0.068	0.190	0.028	1.116

Figure B-11. FTIR Transmission Spectra Data; Gradient from Bondline of Analog Cartons, Sheet 1 of 4

ID#	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 WN	1295 WN	970/ 2850
85B	0.0	1.0357	0.067	0.122	0.048	0.920
#389	0.1	1.0575	0.060	0.145	0.039	1.027
	0.2	1.0285	0.058	0.150	0.038	1.055
	0.3	0.9621	0.062	0.151	0.032	1.082
	0.5	0.9946	0.062	0.144	0.023	1.017
	2.0	0.9806	0.076	0.155	0.022	1.020
86A	0.0	0.9869	0.054	0.094	0.059	0.802
#402	0.1	1.0366	0.052	0.137	0.046	1.000
	0.2	1.0604	0.054	0.139	0.041	0.987
	0.3	0.9768	0.054	0.144	0.042	0.993
	0.5	0.9611	0.055	0.137	0.033	0.936
	2.0	1.0077	0.060	0.169	0.036	1.006
87B	0.0	0.9878	0.043	0.066	0.038	0.823
#412	0.1	0.9881	0.045	0.108	0.028	1.176
	0.2	0.9951	0.048	0.114	0.026	1.215
	0.3	0.9870	0.047	0.112	0.022	1.194
	0.5	1.0287	0.052	0.113	0.016	1.196
	2.0	1.0247	0.056	0.125	0.019	1.133

Figure B-11. FTIR Transmission Spectra Data; Gradient from Bondline of Analog Cartons, Sheet 2 of 4

ID#	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 WN	1295 WN	970/ 2850
85B	0.0	1.0522	0.066000	0.172	0.050	1.090
#387	0.1	1.0669	0.065000	0.117	0.035	1.068
	0.2	1.0626	0.046000	0.131	0.039	1.112
	0.3	1.0523	0.078000	0.122	0.034	1.058
	0.5	1.0712	0.062000	0.134	0.034	1.099
	2.0	1.0194	0.045000	0.152	0.025	1.131
86A	0.0	1.0092	0.049000	0.096	0.032	1.032
#401	0.1	1.0220	0.044000	0.099	0.026	1.135
	0.2	1.0370	0.042000	0.095	0.027	1.114
	0.3	1.0181	0.043000	0.097	0.027	1.138
	0.5	1.0285	0.046000	0.107	0.023	1.134
	2.0	1.0236	0.048000	0.122	0.015	1.157
87B	0.0	1.0210	0.060725	0.104	0.047	0.898
#411	0.1	0.9869	0.044888	0.106	0.039	1.061
BOND	0.2	1.0160	0.042126	0.092	0.038	1.000
	0.3	0.9923	0.042628	0.099	0.047	1.089
	0.5	0.9924	0.046554	0.116	0.047	1.075
	2.0	0.9816	0.051650	0.123	0.026	1.052

Figure B-11. FTIR Transmission Spectra Data; Gradient from Bondline of Analog Cartons, Sheet 3 of 4

ID#	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970 WN	1295 WN	970/ 2850
85B	0.0	1.0769	0.098	0.143	0.049	0.963
#388	0.1	1.0345	0.059	0.118	0.038	1.043
	0.2	0.9889	0.054	0.093	0.040	0.968
	0.3	1.0022	0.057	0.098	0.034	1.043
	0.5	0.9608	0.069	0.172	0.030	1.187
	2.0	0.8816	0.063			
86A	0.0	1.0557	0.052	0.094	0.044	0.861
#406	0.1	1.0371	0.041	0.090	0.037	0.949
	0.2	1.0187	0.040	0.077	0.030	0.857
	0.3	1.0666	0.044	0.087	0.031	0.930
	0.5	1.0874	0.054	0.136	0.031	1.035
	2.0	1.0639	0.049	0.117	0.021	1.000
87F	0.0	1.0369	0.076	0.129	0.057	0.802
#413	0.1	1.0743	0.046	0.106	0.046	0.797
	0.2	1.0523	0.044	0.085	0.040	0.706
	0.3	1.0236	0.044	0.095	0.043	0.789
	0.5	1.0664	0.056	0.151	0.040	0.947
	2.0	1.0038	0.052	0.124	0.026	0.861
88D	0.0	1.0218	0.046	0.088	0.043	0.918
#422	0.1	1.0306	0.044	0.103	0.034	1.071
BOND	0.2	1.0303	0.040	0.089	0.033	1.011
	0.3	1.0441	0.043	0.098	0.031	1.052
	0.5	1.0347	0.056	0.146	0.033	1.135
	2.0	1.0279	0.049	0.125	0.021	1.085

Figure B-11. FTIR Transmission Spectra Data; Gradient from Bondline of Analog Cartons, Sheet 4 of 4

TIME/ TEMP	LOT COMBO	Se/So	GEL-FILLER FRACTION*
0/77	LC 75	1.86	
	LC 76	1.90	0.621
	LC 77	2.02	0.667
	LC 78	1.97	0.671
	LC 79	1.88	0.705
	LC 80A	1.78	0.693
	LC 81A	1.81	0.712
	LC 82E	1.86	0.681
	LC 83	1.85	
	LC 84	1.92	
	LC 85A	1.84	0.696
	LC 85B	1.89	0.670
	LC 86	1.87	0.730
	LC 86A	1.79	0.694
	LC 87B	1.82	0.670
	LC 88D	1.71	0.737
	LC 89A	1.88	0.708
8/135	LC 75	2.17	
	LC 76	2.14	0.583
	LC 77	2.13	0.572
	LC 78	2.19	0.592
	LC 79	2.15	0.582
	LC 80A	2.03	
	LC 81A	1.90	0.608
	LC 82E	1.94	0.626
	LC 83	2.05	0.598
	LC 84	2.04	0.597
	LC 85A	1.96	0.587
	LC 85B	2.01	0.571
	LC 86	1.86	0.591
	LC 86A	1.98	0.593
	LC 87B	1.95	0.591
	LC 88D	2.02	0.602
12/80	LC 76	1.73	0.692
	LC 77	1.89	0.694
	LC 78	1.85	0.708
	LC 79	1.79	0.660
	LC 80A	1.84	0.674
	LC 81A	1.78	0.675
	LC 82E	1.86	0.679
	LC 83	1.86	0.653
	LC 84	1.89	0.648
	LC 85B	1.90	0.611
	LC 86A	1.82	0.644
	LC 87B	1.77	0.689
16/110	LC 75	1.95	
	LC 76	2.01	0.598
	LC 77	1.92	0.594
	LC 78	2.12	0.566
	LC 79	2.01	
	LC 80A	1.95	0.567
	LC 81A	1.98	0.591
	LC 82E	1.99	0.576
	LC 83	2.01	0.545
	LC 84	2.00	0.586
	LC 85B	2.02	0.580
	LC 86A	2.05	0.569
	LC 87B	1.86	0.602

* Gel Filler Fraction Corrected for Variations in Liner Thickness

Figure B-12. Chemical Properties of SD-851-2 Liner Analog Samples from Lot Combinations 75 to 89A

TIME/ TEMP	LOT COMBO	DENSITY	SHORE A METAL	SHORE A 0.25" PROP.	% H2O	Se/So	GEL	DOP
0/77	LC 75	1.216	65	51	1.89	1.75	0.850	4.40
	LC 76	1.215	62	51	1.90	1.74	0.847	5.45
	LC 77	1.217	63	52	1.88	1.76	0.845	5.00
	LC 78	1.221	61	49	1.91	1.79	0.839	6.00
	LC 79	1.205	61	54	1.83	1.81	0.834	5.05
	LC 80A	1.211	62	54	1.75	1.72	0.837	4.80
	LC 81A	1.216	60	53		1.78	0.850	5.49
	LC 82E	1.210	65	57		1.75	0.843	4.79
	LC 83	1.180		58	1.67	1.77	0.842	4.72
	LC 84	1.191	64	52	1.69	1.88	0.835	4.36
	LC 85A	1.208	61	51	1.86	1.79	0.839	4.98
	LC 85B	1.209	64	54	1.38	1.69	0.852	4.54
	LC 86	1.212	64	55	1.91	1.72	0.848	5.95
	LC 86A	1.195	64	58	1.78	1.71	0.846	4.57
	LC 87B	1.207	65	56	1.73	1.71	0.846	5.41
	LC 88D	1.220	71	63	2.04	1.61	0.861	5.56
	LC 89A	1.210	68	55		1.73	0.851	4.52
8/135	LC 75	1.226	71		1.70	1.68	0.894	1.40
	LC 76	1.228	70	57	1.84	1.65	0.900	1.60
	LC 77	1.227	83	67	1.51	1.67	0.904	1.10
	LC 78	1.232	71	66	1.70	1.65	0.908	1.50
	LC 79	1.224	75	68	1.65	1.73	0.891	1.50
	LC 80A	1.242	71	51		1.76	0.928	2.65
	LC 81A	1.230	72	59	1.68	1.71	0.891	1.77
	LC 82E	1.222	70	58	1.71	1.65	0.890	1.65
	LC 83	1.220	68	58	1.61	1.68	0.892	2.63
	LC 84	1.204	61	49	1.54	1.77	0.887	1.73
	LC 85A	1.215	66	55	1.65	1.67	0.895	1.92
	LC 85B	1.216	70	65	1.78	1.65	0.899	1.83
	LC 86	1.213	68	63	1.65	1.69	0.896	1.61
	LC 86A	1.221	71	59	1.20	1.69	0.898	1.20
	LC 87B	1.227	71	58		1.65	0.894	0.91
	LC 88D	1.234			1.84	1.56	0.886	1.87

Figure B-13. Chemical Properties of V-45 Insulation Analog Samples from Lot Combinations 75 to 89A, Sheet 1 of 2

TIME/ TEMP	LOT COMBO	DENSITY	SHORE A METAL	SHORE A 0.25" PROP.	% H2O	Se/So	GEL	DOP
12/80	LC 76	1.225	74	59	2.07	1.76	0.865	3.25
	LC 77	1.218	64	56	2.00	1.79	0.866	3.30
	LC 78	1.218	67	61	2.04	1.76	0.857	3.80
	LC 79	1.207	64	55	1.83	1.80	0.844	3.27
	LC 80A	1.220		56	1.95	1.86	0.847	3.09
	LC 81A	1.220	62	52	1.92	1.71	0.854	3.54
	LC 82E	1.211	60	53	1.99	1.75	0.863	3.04
	LC 83	1.211	63	55	1.74	1.70	0.852	3.31
	LC 84		60	55	1.75	1.80	0.845	3.78
	LC 85B	1.215	69	59	1.96	1.69	0.856	3.25
	LC 86A	1.210	64	58	1.93	1.72	0.857	2.98
	LC 87B	1.219	69		1.95	1.75	0.854	3.79
16/110	LC 75	1.230	71	62	1.65	1.79	0.892	1.50
	LC 76	1.228	68	57	1.70	1.70	0.899	1.50
	LC 77	1.224	72	64	1.75	1.79	0.885	1.60
	LC 78	1.218	71	57	1.78	1.80	0.908	1.49
	LC 79	1.212	62	54	1.67	1.78	0.891	
	LC 80A	1.219	66	47	1.92	1.81	0.884	1.26
	LC 81A	1.221	70	55	2.02	1.72	0.887	1.31
	LC 82E	1.214	66	54	2.09	1.68	0.882	1.87
	LC 83	1.215	68	60	1.87	1.67	0.884	1.77
	LC 84	1.198	69	58	1.66	1.73	0.894	1.93
	LC 85B	1.231	73	59	1.71	1.66	0.899	1.75
	LC 86A	1.222	69		1.88	1.71	0.882	1.54
	LC 87B				1.26	1.70	0.897	1.07

Figure B-13. Chemical Properties of V-45 Insulation Analog Samples from Lot Combinations 75 to 89A, Sheet 2 of 2

Appendix C

Materials From Plug Motors

Test Temperature: 77°F
Strain Rate: 0.74 min^{-1}

Sample Location →		Forward					Mid Barrel					Aft			
Age, mo	Location, Degrees	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	SA	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	SA	σ_m, psi	ε_m, %	ε_b, %	E_o, psi
12	30	138	21	32	1015	57	128	19	32	1227	60	131	18	31	1267
	210						129	19	33	1135					
18	75	135	20	29	1160	61						135	16	27	1369
24	120	141	18	27	1220	62	135	16	27	1367	60				
30		✓					✓					✓			
36		✓										✓			
48		✓					✓					✓			
72		✓					✓								
96							✓					✓			
120		✓										✓			
144		✓					✓					✓			

✓ Designates scheduled test intervals

Figure C-1. Effect of Sample Location and Storage Time on Uniaxial Tensile Properties of Propellant from Motor MSEX-2

Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location	Age mo	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
			Distance from Bondline, Inches															
σ_m, psi	Forward (30°)	12	141	144	145	149	148	142	141	144	150	139	134	125	132	130	130	132
	(75°)	18	116	124	130	130	132	134	135	134	136	134	131	122	122	120	119	120
	(120°)	24	136	126	128	127	128	131	131	132	134	135	134	136	134	134	133	135
		36																
		48																
		72																
		120																
		144																
	Mid Barrel (30°)	12	149	130	136	135	129	126	135	132	131	129	124	122	123	120	114	121
	(210°)	12	133	129	120	129	135	128	129	129	128	128	121	128	124	123	121	123
	(120°)	24	138	129	126	123	128	129	130	132	131	132	131	133	128	130	131	133
		30																
		48																
		72																
		96																
		144																
	Aft (30°)	12	144	136	133	133	133	132	132	131	131	131	130	126	124	122	121	121
	(75°)	18	136	125	122	122	124	124	126	124	124	124	126	125	122	122	121	121
		30																
		36																
		48																
		96																
		120																
		144																

Figure C-2. Effect of Sample Location and Storage Time from Bondline on Uniaxial Tensile Properties of ANB-3066 Propellant, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location	Age mo	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
ϵ_m, %	Forward (30°)	12	10	16	19	21	21	22	22	21	21	20	21	21	21	20	20	21
	(75°)	18	10	16	19	20	20	20	20	18	18	18	19	18	17	18	18	19
	(120°)	24	12	16	17	18	18	18	13	18	18	17	18	17	17	17	17	17
		36																
		48																
		72																
		120																
		144																
	Mid Barrel (30°)	12	12	18	19	19	20	21	21	19	21	20	20	20	18	19	20	19
	(210°)	12	10	16	18	18	18	19	19	20	19	20	20	19	20	21	20	20
	(120°)	24	10	15	18	18	18	17	17	17	17	18	17	16	17	16	16	16
		30																
		48																
		72																
		96																
		144																
	Aft (30°)	12	10	15	18	19	19	20	20	21	20	19	18	18	18	17	18	18
	(75°)	18	10	17	18	19	19	19	19	19	19	13	17	16	16	16	16	17
		30																
		36																
		48																
		96																
		120																
		144																

Figure C-3. Effect of Sample Location, Storage Time, and Distance from Bondline on Uniaxial Tensile Properties of ANB-3006 Propellant, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location	Age mo	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
			Distance from Bondline, Inches															
ϵ_b, %	Forward (30°)	12	10	24	28	29	30	29	29	28	31	28	29	28	27	30	28	30
	(75°)	18	10	20	28	29	29	29	28	26	26	26	26	24	25	25	25	25
	(120°)	24	14	23	22	28	28	27	26	26	26	23	24	25	25	24	23	24
		36																
		48																
		72																
		120																
		144																
	Mid Barrel (30°)	12	12	18	19	19	20	21	21	19	21	20	20	20	18	19	20	19
	(210°)	12	10	25	29	29	29	29	29	31	29	31	27	30	32	30	32	33
	(120°)	24	11	24	29	26	27	28	26	24	25	25	22	24	23	24	23	23
		30																
		48																
		72																
		96																
		144																
	Aft (30°)	12	11	24	30	31	31	30	30	30	29	29	30	30	30	29	27	29
	(75°)	18	10	24	29	29	28	28	30	29	26	26	26	26	26	27	26	28
		30																
		36																
		48																
		96																
		120																
		144																

Figure C-4. Effect of Sample Location, Storage Time, and Distance from Bondline on Uniaxial Tensile Properties of ANB-3006 Propellant, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location	Age mo	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
			Distance from Bondline, Inches															
E_o, psi	Forward (30°)	12	1703	1352	1181	1099	1018	972	959	972	1063	1010	957	876	935	972	943	906
	(75°)	18	1359	1191	1008	1088	1044	1008	1044	1034	1073	1016	1077	1086	1115	1044	1032	1035
	(120°)	24	1451	1312	1194	1122	1114	1085	1092	1107	1077	1114	1085	1092	1106	1166	1121	1121
		36																
		48																
		72																
		120																
		144																
	Mid Barrel (30°)	12	1525	1108	1085	1071	1003	965	1040	1063	1048	1039	1018	1041	1039	972	950	1017
	(210°)	12	1517	1219	1025	1116	1137	1055	1048	1010	1017	1063	958	1003	921	876	928	921
	(120°)	24	1762	1294	1095	1052	1067	1075	1080	1124	1132	1147	1183	1184	1110	1161	1235	1073
		30																
		48																
		72																
		96																
		144																
	Aft (30°)	12	1633	1373	1165	1151	1136	1135	1099	1070	1076	1076	1113	1106	1114	1091	1069	1046
	(75°)	18	1696	1169	1078	1090	1063	1005	1084	1074	1066	1022	1138	1162	1147	1124	1109	1083
		30																
		36																
		48																
		96																
		120																
		144																

Figure C-5. Effect of Sample Location, Storage Time, and Distance from Bondline on Uniaxial Tensile Properties of ANB-3006 Propellant, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Applied Strain: 2.0%

Property	Sample Location	Age mo	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
			Distance from Bondline, Inches															
E_{r_1}, psi	Forward (30°)	12	1007	692	553	543	526	534	552	471	482	461	497	518	437	458	459	449
	(75°)	18	954	621	574	533	552	570	557	573	605	590	576	678	670	636	690	666
	(120°)	24	1219	905	728	733	717	663	679	763	753	753	734	776	748	775	762	-
		36																
		48																
		72																
		120																
		144																
	Mid Barrel (30°)	12	926	604	533	485	490	468	494	449	427	446	483	483	500	488	504	505
	(210°)	12	960	671	613	631	577	580	582	566	557	523	547	484	526	521	516	482
	(120°)	24	1200	889	814	774	793	737	715	754	769	741	844	809	778	821	831	786
		30																
		48																
		72																
		96																
		144																
	Aft (30°)	12	963	659	610	576	575	577	597	560	549	523	508	556	578	600	577	571
	(75°)	18	1018	691	609	612	610	630	557	600	582	586	697	712	736	718	746	724
		30																
		36																
		48																
		96																
		120																
		144																

Figure C-6. Effect of Sample Location, Storage Time, and Distance from Bondline on Relaxation Modulus of ANB-3006 Propellant, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Applied Strain: 2.0%

Sample Location →		Forward			Mid Barrel			Aft		
		Relaxation Modulus, E_r, psi at Time t, Minutes			Relaxation Modulus, E_r, psi at Time t, Minutes			Relaxation Modulus, E_r, psi at Time t, Minutes		
Age mo	Location	0.1	1.0	10.0	0.1	1.0	10.0	0.1	1.0	10.0
	30°				787	507	387			
12	210°	748	491	385	848	538	406	936	612	472
18	75°	967	629	493				1094	722	569
24	120°	1258	810	629	1211	789	622			
30										
36										
48										
72										
96										
120										
144										

Figure C-7. Effect of Sample Location, Storage Time, and Distance from Bondline on Relaxation Modulus of ANB-3006 Propellant, Motor MSEX-2 (1984A)

LOCATION	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970/ IW	1295/ IW	970/ 2850
MID-BARREL (210 DEG) 12 Mo.	0.0	1.0713	0.051	0.094	0.033	0.894
	0.1	1.0689	0.060	0.167	0.036	1.113
	0.2	1.0917	0.062	0.169	0.035	1.101
	0.3	1.0591	0.064	0.170	0.032	1.084
	0.5	1.0844	0.062	0.164	0.028	1.079
	2.0	1.0793	0.070	0.165	0.025	1.085
MID-BARREL (30 DEG) 12 Mo.	0.0	0.9969	0.051	0.091	0.032	0.910
	0.1	1.0805	0.059	0.163	0.036	1.107
	0.2	1.0307	0.061	0.170	0.035	1.108
	0.3	1.0394	0.062	0.169	0.032	1.114
	0.5	1.0911	0.062	0.170	0.029	1.088
	2.0	1.0406	0.065	0.161	0.020	1.098
MID-BARREL (120 DEG) 24 Mo.	0.0	1.0099	0.048	0.088	0.035	1.072
	0.1	1.0336	0.056	0.154	0.036	1.252
	0.2	1.0558	0.058	0.158	0.033	1.275
	0.3	1.0212	0.063	0.155	0.031	1.234
	0.5	0.9909	0.067	0.153	0.029	1.216
	2.0	1.0119	0.060	0.145	0.019	1.205
FORWARD END (30 DEG) 12 Mo.	0.0	1.0913	0.052	0.103	0.049	0.896
	0.1	1.0448	0.063	0.159	0.047	1.099
	0.2	1.0404	0.062	0.163	0.039	1.104
	0.3	1.0468	0.061	0.162	0.035	1.069
	0.5	1.0657	0.062	0.160	0.028	1.069
	2.0	1.0518	0.061	0.154	0.022	1.038
FORWARD END (25 DEG) 18 Mo.	0.0	1.0415	0.049	0.131	0.057	1.172
	0.1	1.0920	0.057	0.179	0.054	1.250
	0.2	1.0728	0.055	0.173	0.044	1.177
	0.3	1.0773	0.058	0.182	0.046	1.233
	0.5	1.0736	0.058	0.168	0.033	1.161
	2.0	1.0943	0.058	0.164	0.027	1.162
FORWARD END (120 DEG) 24 Mo.	0.0	1.0225	0.056	0.102	0.051	1.010
	0.1	0.9840	0.062	0.153	0.044	1.189
	0.2	1.0564	0.060	0.156	0.038	1.179
	0.3	1.0242	0.060	0.161	0.039	1.179
	0.5	1.0024	0.061	0.151	0.029	1.208
	2.0	1.0416	0.063	0.135	0.018	1.195

Figure C-8. Plugs from Motor MSEX-2, Transmission Spectra of Chloroform Extractables, Peak Heights Normalized to Initial Weights Gradient from the Bondline Interface, Sheet 1 of 2

LOCATION	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970/ IW	1295/ IW	970/ 2850
AFT END (30 DEG)	0.0	1.0625	0.049	0.093	0.042	1.000
12 Mo.	0.1	1.0452	0.061	0.165	0.040	1.229
	0.2	1.0783	0.063	0.172	0.041	1.208
	0.3	1.0162	0.069	0.172	0.037	1.207
	0.5	1.0933	0.071	0.165	0.027	1.169
	2.0	1.0468	0.056	0.160	0.021	1.159
AFT END (75 DEG)	0.0	1.0753	0.052	0.113	0.050	1.052
13 Mo.	0.1	1.0982	0.057	0.173	0.050	1.218
	0.2	1.0801	0.058	0.181	0.052	1.250
	0.3	1.0745	0.058	0.176	0.044	1.219
	0.5	1.0900	0.057	0.176	0.035	1.164
	2.0	1.0748	0.055	0.170	0.030	1.188
BORE	0.0	1.0244	0.053	0.129	0.020	1.168
24 Mo.	0.1	1.0029	0.054	0.142	0.022	1.145
	0.2	1.0357	0.056	0.135	0.024	1.148
	0.3	1.0108	0.054	0.135	0.027	1.172
	0.5	1.0097	0.052	0.128	0.029	1.194
	1.5	1.0312	0.065	0.144	0.028	1.203

Figure C-8. Plugs from Motor MSEX-2, Transmission Spectra of Chloroform Extractables, Peak Heights Normalized to Initial Weights Gradient from the Bondline Interface, Sheet 2 of 2

Type Test: Double Plate Tensile
Type Specimen: Mini Double Plate
Test Temperature: 77°F
Crosshead Rate: 0.5 in./min

	Sample Location →	Forward						Mid Barrel						Aft					
				Type Failure, %						Type Failure, %						Type Failure, %			
Age, mo	Location	Stress, psi	Time-to-Fail., min	CP	APL	CL	ALI	Stress, psi	Time-to-Fail., min	CP	APL	CL	ALI	Stress, psi	Time-to-Fail., min	CP	APL	CL	ALI
12	30°	104	0.23		95	5		78	0.21		90	10		102	0.22		85	15	
	210°							105	0.21		90	5	5						
18	75°	98	0.19		80	20								120	0.18		85	15	
24	120°	78	0.23		85	15		102	0.20		80	20							
30																			
36																			
48																			
72																			
96																			
120																			
144																			

Figure C-9. Effect of Sample Location and Storage Time on Bond Tensile Strength of ANB-3006/SD-851-2/V-45 Bond System, Plug Motor MSEX-2 (1984A)

Type Test: High Rate Shear
Test Temperature: 77°F
Crosshead Rate: 200 in./min
Superimposed Pressure: 600 psig

	Sample Location ——→	Forward						Mid Barrel						Aft					
				Type Failure, %						Type Failure, %						Type Failure, %			
Age mo	Location	Stress, psi	Time-to-Fail., sec	CP	APL	CL	ALI	Stress, psi	Time-to-Fail., sec	CP	APL	CL	ALI	Stress, psi	Time-to-Fail., sec	CP	APL	CL	ALI
12	30°	209	0.12		45	55		236	0.11		50	50		228	0.12		50	50	
	210°							243	0.13		45	55							
18	75°	219	0.09		35	65								224	0.10		50	50	
24	120°	210	0.10		35	65		249	0.08		45	55							
30																			
36																			
48																			
72																			
96																			
120																			
144																			

Figure C- 7. Effect of Sample Location and Storage Time on Bond Shear Strength of ANB-3066/SD-851-2/V-45 Bond System, Plug Motor MSEX-2 (1984A)

Test Temperature: 77°F
Applied Strain: 2.0%

Sample Location →		Forward			Mid Barrel			Aft		
		Relaxation Modulus, E_r, psi at Time t, Minutes			Relaxation Modulus, E_r, psi at Time t Minutes			Relaxation Modulus, E_r, psi at Time t, Minutes		
Age mo	Location	0.1	1.0	10.0	0.1	1.0	10.0	0.1	1.0	10.0
12	30°	1633	1285	1102	925	704	604	1687	1312	1107
	210°				-	-	-			
18	75°	1602	1259	1067				1082	826	688
24	120°	1967	1555	1366	1505	1160	972			
30										
36										
48										
72										
96										
120										
144										

Figure C-11. Effect of Sample Location and Storage Time on Pelaxation Modulus of V-45 Insulation, Motor MSEX-2 (1984A)

Test Temperature: 77°F
Strain Rate: 0.74 min^{-1}

	Sample Location →		Forward					Mid-Barrel					Aft				
Age, mo	Test Interval	Location	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	SA	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	SA	σ_m, psi	ε_m, %	ε_b, %	E_o, psi	SA
110	0	30°	143	16	22	1385	64	154	15	21	1582	64	144	15	20	1471	60
		210°						152	14	19	1648	58					
	1	120°															
	2	75°															
		120°															
	3	210°															
	4	165°															
	5	300°															
		345°															
	8	300°															
	10	345°															
	12	255°															

Figure C-12. Effect of Sample Location and Storage Time on Uniaxial Tensile Properties of ANB-3066 Propellant Plug Motor AA21450 (1976A)

Type Specimen: Mini Uniaxial Tensile
Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location (Deg)	Age mo (yrs)	Test Interval	Distance from Bondline, Inches 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
σ_m, psi	Forward (30)	110 (9)	0	136	127	124	125	124	128	128	130	131	131	135	136	136	136	134	133
			1																
			3																
			4																
			6																
			10																
			12																
	Mid-Barrel (30)	110 (9)	0	136	141	137	141	140	140	141	140	142	143	142	143	143	141	142	-
	(210)	110 (9)	0	142	145	140	138	138	141	141	142	143	142	146	145	145	143	142	142
			1																
			2																
			4																
			6																
			8																
			12																
	Aft (30)	110 (9)	0	108	131	124	126	128	129	129	131	133	133	138	142	140	140	138	136
			2																
			3																
			4																
			8																
			10																
			12																

Figure C-13. Effect of Storage Time and Distance from Bondline on Nominal Maximum Stress for ANB-3066 Propellant Removed from Plugged Motor AA21480

Type Specimen: Mini Uniaxial Tensile
Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location (Deg)	Age mo (yrs)	Test Interval	Distance from Bondline, Inches 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
ϵ_m, %	Forward (30)	110 (9)	0	10	17	18	17	18	18	17	17	18	17	16	16	15	16	16	16
			1																
			3																
			4																
			6																
			10																
			12																
	Mid-Barrel (30)	110 (9)	0	9	16	17	17	17	17	17	17	16	16	16	16	16	15	15	-
	(210)	110 (9)	0	9	15	17	15	16	15	16	16	16	16	16	16	15	16	16	16
			1																
			2																
			4																
			6																
			8																
			12																
	Aft (30)	110 (9)	0	8	17	19	19	18	18	18	17	17	17	17	17	16	16	16	16
			2																
			3																
			4																
			8																
			10																
			12																

Figure C-14. Effect of Storage Time and Distance from Bondline on Strain at Nominal Stress for ANB-3066 Propellant Removed from Plugged Motor AA21480

Type Specimen: Mini Uniaxial Tensile
Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location (Deg)	Age mo (yrs)	Test Interval	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
				Distance from Bondline, Inches															
ε_b, %	Forward (30)	110 (9)	0	10	25	27	26	26	26	25	26	24	25	21	21	20	20	22	22
			1																
			3																
			4																
			6																
			10																
			12																
	Mid-Barrel (30)	110 (9)	0	9	22	25	24	24	25	23	22	25	22	22	22	22	21	21	-
	(210)	110 (9)	0	10	20	24	22	21	22	23	20	22	23	22	20	20	22	20	22
			1																
			2																
			4																
			6																
			8																
			12																
	Aft (30)	110 (9)	0	8	24	26	28	27	25	27	24	25	24	22	24	22	22	24	22
			2																
			3																
			4																
			8																
			10																
			12																

Figure C-15. Effect of Storage Time and Distance from Bondline on Strain at Break for ANB-3066 Propellant Removed from Plugged Motor AA21480

Type Specimen: Mini Uniaxial Tensile
Test Temperature: 77°F
Strain Rate: 1.0 min^{-1}

Property	Sample Location (Deg)	Age mo (yrs)	Test Interval	Distance from Bondline, Inches 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
E_0, psi	Forward (30)	110 (9)	0	1725	1091	1009	1030	1001	1068	1048	1084	1069	1106	1142	1216	1216	1253	1194	1186
			1																
			3																
			4																
			6																
			10																
			12																
	Mid-Barrel (30)	110 (9)	0	1728	1234	1161	1183	1183	1190	1220	1256	1257	1308	1286	1315	1300	1323	1264	-
	(210)	110 (9)	0	1880	142[illegible]	1249	1235	1257	1250	1279	1301	1286	1287	1338	1338	1330	1316	1293	1279
			1																
			2																
			4																
			6																
			8																
			12																
	Aft (30)	110 (9)	0	1528	1139	1014	1036	1058	1051	1081	1125	1197	1153	1205	1249	1263	1264	1241	1205
			2																
			3																
			4																
			8																
			10																
			12																

Figure C-16. Effect of Storage Time and Distance from Bondline on Initial Tangent Modulus for ANB-3066 Propellant Removed from Plugged Motor AA2148U

Test Temperature: 77°F
Applied Strain: 2.0%

Property	Sample Location (Deg)	Age mo (yrs)	Test Interval	Distance from Bondline, Inches 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.5	2.0	2.5	3.0	3.5	4.0
E_{τ_1}, psi	Forward (30)	110 (9)	0	1296	622	592	538	572	608	628	597	630	726	662	726	823	831	840	-
			1																
			3																
			4																
			6																
			10																
			12																
	Mid-Barrel (30)	110 (9)	0	1850	984	820	805	779	785	857	831	842	933	878	879	921	1018	900	-
	(210)	110 (9)	0	-	1018	900	920	936	942	933	906	951	1032	994	1045	1070	931	1042	1005
			1																
			2																
			4																
			6																
			8																
			12																
	Aft (30)	110 (9)	0	1331	724	665	721	723	785	715	764	785	776	900	872	881	856	876	820
			2																
			3																
			4																
			8																
			10																
			12																
	Excise (Aft End)	110 (9)	0	1078	940	952	985	1010	978	986	978	923	953	444	456				

Figure C-17. Effect of Storage Time and Distance from Bondline on Relaxation Modulus for ANB-3066 Propellant Removed from Plugged Motor AA21480

Type Test: Double Plate Tensile
Type Specimen: Mini Double Plate
Test Temperature: 77°F
Crosshead Rate: 0.5 in./min

Sample Location →			Forward						Mid-Barrel						Aft					
Age, mo	Test Interval	Location	Stress, psi	Time to Fail, min	Type Failure, % CP	APL	CL	F	Stress, psi	Time to Fail, min	Type Failure, % CP	APL	CL	F	Stress, psi	Time to Fail, min	Type Failure, % CP	APL	CL	F
110	0	30°	102	0.103		50	50		113	0.089		75	25		100	0.106		100		
		210°							114	0.094		65	35							
	1	120°																		
	2	75°																		
		120°																		
	3	210°																		
	4	165°																		
	6	300°																		
		345°																		
	8	300°																		
	10	345°																		
	12	255°																		

Figure C-18. Effect of Specimen Location and Storage Time on Bond Tensile Strength of ANB-3066/SD-851-2 Bond System Plug Motor AA21480 (1976A)

Type Test: High Rate Shear
Type Specimen: Poker Chip
Test Temperature: 77°F
Crosshead Rate: 200 in./min
Superimposed Pressure: 600 psig

Sample Location →			Forward						Mid-Barrel						Aft					
Age, mo	Test Interval	Location	Stress, psi	Time to Fail, sec	Type Failure, % CP	APL	CL	F	Stress, psi	Time to Fail, sec	Type Failure, % CP	APL	CL	F	Stress, psi	Time to Fail, sec	Type Failure, % CP	APL	CL	F
110	0	30°	214	0.132		30	70		269	0.083		35	65		224	0.112		40	60	
		210°							260	0.086		40	60							
	1	120°																		
	2	75°																		
		120°																		
	3	210°																		
	4	165°																		
	6	300°																		
		345°																		
	8	300°																		
	10	345°																		
	12	255°																		

Figure C-19. Effect of Specimen Location and Storage Time on Bond Shear Strength of ANB-3066/SD-851-2 Bond System Plug Motor AA21480 (1976A)

LOCATION	DISTANCE INCHES	INITIAL WEIGHT	SOL FRAC	970/ IW	1295/ IW	970/ 2850
MID-BARREL (30 DEG)	0.0	1.0270	0.050	0.067	0.019	0.670
	0.1	1.0616	0.065	0.121	0.024	0.977
	0.2	1.0440	0.065	0.129	0.021	0.993
	0.3	1.0345	0.066	0.130	0.020	0.978
	0.5	1.0150	0.069	0.129	0.020	0.985
	2.0	1.0419	0.065	0.119	0.012	0.939
MID-BARREL (210 DEG)	0.0	1.0400	0.049	0.067	0.018	0.761
	0.1	1.0405	0.059	0.114	0.019	1.044
	0.2	1.0627	0.054	0.124	0.020	1.073
	0.3	0.9277	0.059	0.133	0.025	1.017
	0.5	1.0333	0.061	0.130	0.023	1.039
	2.0	1.0357	0.067	0.121	0.017	1.025
FORWARD (30 DEG)	0.0	1.0122	0.051	0.065	0.043	0.725
	0.1	1.0451	0.062	0.132	0.043	1.062
	0.2	1.0667	0.061	0.137	0.040	1.058
	0.3	1.0265	0.063	0.133	0.035	1.070
	0.5	1.0559	0.061	0.134	0.035	1.068
	2.0	1.0384	0.064	0.119	0.014	0.947
AFT END (30 DEG)	0.0	0.9833	0.062	0.073	0.050	0.758
	0.1	1.0447	0.059	0.129	0.043	1.116
	0.2	1.0398	0.071	0.136	0.045	1.093
	0.3	0.9782	0.064	0.138	0.041	1.134
	0.5	1.0208	0.076	0.134	0.034	1.132
	2.0	1.0024	0.074	0.124	0.018	1.078

Figure C-20. Plugs from AA21480 (1976 Vintage, 110 Mo) Transmission Spectra of Chloroform Extractables, Peak Heights Normalized to Initial Weight Gradient from Bondline Interface

SOURCE	SAMPLE TYPE	AGE MONTHS	Se/So	CORRECTED GEL
MSEX-2	EXCISE	2.5	1.88	0.703
MSEX-2	EXCISE	24.0	1.89	0.613
MSEX-2	ANALOG (n = 3)	12.0	1.80 (.04)	.652 (.009)
MSEX-2	ANALOG (N=1)	24.0	1.87	0.612
MSEX-2	MID-BARREL (30 DEG)	12.0	1.89	0.678
MSEX-2	MID-BARREL (210 DEG)	12.0	1.65	0.668
MSEX-5	MIDBARREL (120 DEG)	24.0	1.69	0.658
MSEX-2	FORWARD END (30 DEG)	12.0	1.87	0.671
MSEX-2	FORWARD END (75 DEG)	18.0	1.70	0.666
MSEX-2	FORWARD END (120 DEG)	24.0	1.72	0.633
MSEX-2	AFT END (30 DEG)	12.0	1.70	0.670
MSEX-2	AFT END (75 DEG)	18.0	1.84	0.699
AA21480	MIDBARREL (30 DEG)	110.0	1.68	0.678
AA21480	MIDBARREL (210 DEG)	110.0	1.83	0.680
AA21480	FORWARD (30 DEG)	110.0	1.76	0.637
AA21480	AFT (30 DEG)	110.0	1.68	0.645
AA21480	EXCISE	110.0	1.89	0.454

*** Gel Filler Fraction Corrected for Variations in Liner Thickness**

Figure C-21. Chemical Prpoerties of SD-851-2 Liner

SOURCE	SAMPLE TYPE	AGE MONTHS	DENSITY	SHORE A METAL	% MOISTURE	SWELLING RATIO	GEL FILLER FRACTION	% DOP
MSEX-2	EXCISE	2.5			1.88	1.73	0.848	5.97
MSEX-2	EXCISE	24.0		71	1.94		0.856	3.40
MSEX-2	ANALOG (n = 3)	12.0	1.200 (.001)	66 (1)	1.80 (.02)	1.74 (.01)	.861 (.002)	3.38 (.09)
MSEX-2	ANALOG (n=1)	24.0	1.219	68	1.94	1.74	0.864	2.67
MSEX-2	MID-BARREL (30 DEG)	12.0	1.193	66	1.69	1.68	0.874	1.75
MSEX-2	MID-BARREL (210 DEG)	12.0	1.173	68	1.90	1.67	0.873	1.79
MSEX-2	MID-BARREL (120 DEG)	24.0	1.234	70	1.73	1.69	0.882	1.04
MSEX-2	FORWARD END (30 DEG)	12.0	1.203	65	1.61	1.75	*0.845/0.834	*4.89/5.71
MSEX-2	FORWARD END (75 DEG)	18.0	1.216	67	1.52	1.72	0.842	5.95
MSEX-2	FORWARD END (120 DEG)	24.0	1.212	66	1.51	1.74	*0.846/0.832	*4.21/6.30
MSEX-2	AFT END (30 DEG)	12.0	1.201	66	1.32	1.73	*0.847/0.844	*5.01/5.75
MSEX-2	AFT END (75 DEG)	18.0	1.218	69	1.63	1.74	0.843	5.74
AA21480	MID-BARREL (30 DEG)	110.0	1.262	75	1.79	1.68	0.899	0.48
AA21490	MID-BARREL (210 DEG)	110.0	1.212	73	1.95	1.67	0.898	0.51
AA21480	FORWARD (30 DEG)	110.0	1.218	73	1.59	1.66	*0.863/0.848	*3.13/5.94
AA21480	AFT (30 DEG)	110.0	1.218	72	1.75	1.66	*0.861/0.846	*3.26/4.67
AA21480	AFT BOOT EXCISE	110.0			1.77	1.64	0.890	1.67

*Insulation near liner/case

Figure C-22. Chemical Properties of V-45 Insulation

Appendix D

Components

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	IGNITER S/N	DELAY MILLISEC	DURATION SEC	AVG PRES PSI	MAX PRES. PSI	Pdt PSI/SEC	AGE MON.	DATE FIRED	LOT	FIRED FOR	REMARKS
1	2026066	9.0	0.312	940	990	293.0	2	14-MAY-65	3	POA	POA6-2
2	2026067	9.0	0.299	965	1010	288.0	2	28-APR-65	3	POA	POA6-1
3	2026080	9.5	0.279	1023	1115	295.0	2	28-MAY-65	4	POA	POA6-3
4	2026122	8.0	0.269	1075	1150	289.0	2	30-JUN-65	5	POA	POA6-6
5	2026123	9.0	0.274	1035	1105	294.0	2	16-JUL-65	5	POA	POA6-7
6	2026143	10.0	0.290	958	1018	278.0	109	5-74	6	OP	OP20-20025
7	2026149	10.0	0.300	950	1104	285.0	198	11-81	7	OP	OP57-20045
8	2026159	8.0	0.290	960	1040	278.0	2	14-OCT-65	7	POA	POA6-9
9	2026162	10.0	0.299	936	1022	280.0	2	17-AUG-65	7	POA	POA6-8
10	2026166	8.0	0.307	903	1021	277.0	23	12-68	8	OP	OP3-20013
11	2026197	7.0	0.304	935	1124	284.0	2	29-OCT-65	9	POA	POA6-10
12	2026207	8.0	0.307	903	1021	277.0	149	11-77	9	OP	OP43-20041
13	2026255	9.0	0.317	932	1126	303.0	114	1-75	11	OP	OP24-20027
14	2026285	10.0	0.270	1024	1188	277.0	193	9-81	12	OP	OP56-20051
15	2026288	7.0	0.270	1022	1227	277.0	134	10-76	12	OP	OP33-20056
16	2026305	7.0	0.267	1027	1360	274.0	2	19-NOV-65	13	POA	POA6-11
17	2026320	10.0	0.270	1033	1363	279.0	140	5-77	13	OP	OP35-20042
18	2026330	4.0	0.278	1043	1248	290.0	177	6-80	14	OP	OP54-20104
19	2026332	2.0	0.283	1046	1327	296.0	154	8-78	14	OP	OP46-20090
20	2026336	9.0	0.273	1056	1269	289.0	110	12-74	14	OP	OP23-20020
21	2026358	6.0	0.279	1041	1122	291.0	171	12-79	15	OP	OP50-20048
22	2026364	8.0	0.277	1057	1192	293.0	157	11-78	15	OP	OP47-20110
23	2026380	6.0	0.280	997	1140	279.0	18	3-67	16	AGING	
24	2026381	7.0	0.280	1016	1242	289.0	18	3-67	16	AGING	
25	2026382	7.0	0.280	1032	1176	289.0	18	3-67	16	AGING	
26	2026383	7.0	0.278	1036	1277	288.0	18	3-67	16	AGING	
27	2026385	9.0	0.277	1046	1171	290.0	72	9-71	16	AGING	
28	2026386	8.0	0.279	1047	1169	292.0	72	9-71	16	AGING	
29	2026387	7.0	0.279	1063	1180	296.0	72	9-71	16	AGING	
30	2026388	8.0	0.285	1033	1190	294.0	72	9-71	16	AGING	
31	2026391	9.0	0.280	1036	1192	290.0	239	9-85	16	VECP	
32	2026393	7.0	0.283	1052	1201	298.0	121	10-75	16	AGING	
33	2026394	6.0	0.291	1040	1290	303.0	128	4-76	16	AGING	
34	2026395	10.0	0.279	1042	1255	290.8	236	8-85	16	VECP	
35	2026405	10.0	0.280	1027	1181	288.0	147	6-78	17	OP	OP45-20028
36	2026407	8.0	0.292	991	1146	290.0	95	12-73	17	OP	OP19-173
37	2026409	9.0	0.313	1003	1149	323.0	98	1-76	17	OP	AA20071
38	2026417	6.0	0.289	1030	1158	297.0	210	8-82	17	OP	OP59-20026
39	2026434	6.0	0.272	1075	1317	292.0	239	9-85	18	VECP	UNSEALED
40	2026437	9.0	0.279	1056	1170	294.5	238	8-85	18	VECP	UNSEALED
41	2026455	7.0	0.288	1008	1053	290.0	48	10-69	19	AGING	
42	2026456	7.0	0.287	1000	1091	289.0	48	10-69	19	AGING	
43	2026457	7.0	0.290	1000	1111	290.0	48	10-69	19	AGING	
44	2026458	7.0	0.287	989	1055	284.0	48	10-69	19	AGING	
45	2026460	6.0	0.277	1052	1119	291.0	96	10-73	19	AGING	
46	2026461	6.0	0.287	1015	1094	291.0	96	10-73	19	AGING	
47	2026462	5.0	0.292	995	1070	290.0	96	10-73	19	AGING	
48	2026463	6.0	0.288	1007	1111	289.0	96	10-73	19	AGING	
49	2026468	18.0	0.317	1022	1105	311.0	100	3-74	19		0052MS3
50	2026431	7.0	0.285	1030	1132	293.5	237	8-85	20	VECP	UNSEALED
51	2026492	8.0	0.292	991	1133	289.0	247	4-86	20	VECP/AGING	
52	2026494	19.0	0.287	1022	1160	293.3	237	8-85	20	VECP	UNSEALED
53	2026508	8.0	0.281	1093	1118	293.0	236	8-85	21	VECP	UNSEALED
54	2028514	5.0	0.278	1053	1178	293.0	237	9-85	21	VECP	UNSEALED

Figure D-1. Igniter "allistic Data, Sheet 1 of 3

	IGNITER S/N	DELAY MILLISEC	DURATION SEC	AVG PRES PSI	MAX PRES. PSI	P-DL PSI/SEC	AGE MON.	DATE FIRED	LOT	FIRED FOR	REMARKS
55	2026539	18.0	0.286	1024	1112	293.0	231	9-85	22	VECP	UNSEALED
56	2026633	9.0	0.279	1041	1122	290.0	156	5-73	26	OP	AA20098
57	2026663	9.0	0.283	1063	1198	300.8	231	8-85	27	VECP	UNSEALED
58	2026664	10.0	0.285	1018	1177	290.0	232	9-85	27	VECP	UNSEALED
59	2026683	8.0	0.277	1100	1178	305.0	182	7-81	28	OP	OP55-20167
60	2026710	10.0	0.275	974	1173	268.0	124	11-76	29	OP	OP32-20133
61	2026721	8.0	0.303	974	1044	303.0	115	2-76	29	OP	AA20097
62	2026787	17.0	0.275	992	1167	272.8	227	8-85	32	VECP	UNSEALED
63	2026789	18.0	0.279	975	1102	272.0	227	8-85	32	VECP	UNSEALED
64	2026857	12.0	0.279	959	1090	272.0	195	11-82	35	OP	OP60-20043
65	2026894	10.0	0.256	1042	1204	267.0	236	3-86	36	VECP/AGING	
66	2026890	10.0	0.251	1079	1301	271.0	236	3-86	36	VECP/AGING	
67	2026894	7.0	0.279	987	1097	275.0	110	6-74	36	OP	OP21-20046
68	2026906	10.0	0.278	987	1100	274.0	159	1-81	37	OP	OP53-20094
69	2026908	12.0	0.273	981	1099	268.0	196	4-83	37	OP	OP61-20074
70	2026956	6.0	0.279	1041	1122	290.0	156	7-73	39	OP	OP17-20048
71	2026961	10.0	0.290	958	1018	278.0	87	4-74	39	OP	AA20022
72	2027033	10.0	0.279	962	1073	269.0	228	4-86	42	VECP/AGING	
73	2027039	21.0	0.276	968	1067	267.0	221	9-85	42	VECP	UNSEALED
74	2027046	17.0	0.277	993	1117	275.0	221	9-85	42	VECP	UNSEALED
75	2027063	18.0	0.305	964	1035	311.0	109	8-74	43	OP	AA20073
76	2027081	18.0	0.304	1024	1108	312.0	110	5-76	44	OP	OP31-20472
77	2027084	13.0	0.281	1060	1170	298.0	217	9-85	44	VECP	UNSEALED
78	2027087	14.0	0.299	1027	1162	307.0	197	1-84	44	OP	OP63-20101
79	2027141	16.0	0.271	1022	1122	277.0	214	9-85	46	VECP	UNSEALED
80	2027177	11.0	0.292	1003	1081	293.0	216	3-86	48	VECP/AGING	
81	2027186	12.0	0.298	973	1062	290.0	216	3-86	48	VECP/AGING	
82	2027216	11.0	0.312	998	1113	311.0	104	1-77	49	OP	AA20103
83	2027330	20.0	0.277	963	1041	266.0	195	1-86	54	VECP	UNSEALED
84	2027332	15.0	0.279	971	1071	271.0	195	1-86	54	VECP	2ES
85	2027333	15.0	0.278	981	1095	273.6	190	8-85	54	VECP	UNSEALED
86	2027334	15.0	0.278	975	1083	271.0	195	1-86	54	VECP	UNSEALED
87	2027337	19.0	0.271	1008	1114	273.2	190	8-85	54	VECP	UNSEALED
88	2027338	15.0	0.280	960	1062	269.0	195	1-86	54	VECP	2HS
89	2027340	14.0	0.283	973	1060	274.0	195	1-86	54	VECP	2HS
90	2027342	10.0	0.281	982	1105	276.0	195	1-86	54	VECP	UNSEALED
91	2027520	10.0	0.265	1049	1223	278.0	2		62	POA	POA6-51
92	2027545	13.0	0.277	1034	1099	287.0	2		63	POA	POA6-50
93	2027600	15.0	0.260	1062	1138	276.0	2		65	POA	POA6-52
94	2027645	15.0	0.267	977	1049	261.0	2		66	POA	POA6-53
95	2027650	18.0	0.258	1025	1110	262.0	2		67	POA	POA6-54
96	2027675	15.0	0.257	1074	1160	276.0	2		68	POA	POA6-55
97	2027700	10.0	0.287	986	1070	283.0	2	17-JUL-72	69	POA	POA6-57
98	2027725	11.0	0.258	1049	1112	270.0	2	10-FEB-73	70	POA	POA6-61
99	2027750	11.0	0.261	1044	1114	273.0	2	22-MAY-72	71	POA	POA6-56
100	2027803	9.0	0.269	1032	1104	277.0	2	28-SEP-72	73	POA	POA6-58
101	2027825	15.0	0.269	1030	1128	278.0	2	26-OCT-72	74	POA	POA6-59
102	2027850	11.0	0.267	1031	1102	270.0	2	27-NOV-72	75	POA	POA6-60
103	2027875	13.0	0.260	1058	1159	276.0	2	12-MAR-73	76	POA	POA6-62
104	2027900	11.0	0.270	1032	1107	282.0	2	14-MAY-73	78	POA	POA6-64
105	2027925	11.0	0.271	1028	1102	278.0	2	10-MAY-73	78	POA	POA6-63
106	2027950	19.0	0.273	1019	1072	278.0	2	06-AUG-73	79	POA	POA6-65
107	2028050	11.0	0.258	1069	1137	276.0	2	20-MAR-74	83	POA	POA6-69
108	2028075	9.0	0.276	1028	1096	284.0	2	13-MAY-74	84	POA	POA6-70

Figure D-1. Igniter Ballistic Data, Sheet 2 of 3

IGNITER2 141F x 11C 11-APR-86 12:09 Page 3

	IGNITER S/N	DELAY MILLISEC	DURATION SEC	AVG PRES PSI	MAX PRES. PSI	Pdt PSI/SEC	ACC NUM.	DATE FIRED	LOT	FIRED FOR	REMARKS
109	2028151	12.0	0.265	1042	1117	276.0	2	26-AUG-74	87	POA	POA6-73
110	2028176	10.0	0.263	1049	1136	275.0	2	20-AUG-74	88	POA	POA6-72
111	2028276	13.0	0.275	1032	1089	284.0	2	16-JAN-75	92	POA	POA6-75
112	2028477	9.0	0.276	1015	1113	280.0	2	10-APR-78	101	POA	POA6-85
113	2028779	11.0	0.256	1099	1114	291.0	2	05-JUN-84	114	POA	POA6-105
114	2028873	8.0	0.257	1064	1134	[illegible]	2	07-SEP-84	118	POA	POA6-106
115	2028922	8.0	0.257	1092	1150	278.0	2	15-SEP-83	120	POA	POA6-102
116	2028987	10.0	0.260	1072	1159	279.0	2	26-FEB-85	123	POA	POA6-107
117		5.0	0.279	1004	1106	271.0	2	07-SEP-81		POA	POA6-95
118		8.0	0.274	1020	1044	280.0	2	25-NOV-75		POA	POA6-78
119		8.0	0.275	1042		287.0	2	21-JUL-77		POA	POA6-84
120		8.0	0.252	1092	1236	275.0	2	24-MAY-84		POA	POA6-104
121		9.0	0.290	989	1052	286.0	2	27-FEB-78		POA	POA6-86
122		9.0	0.256	1080	1095	277.0	2	16-APR-82		POA	POA6-97
123		9.0	0.264	1048	1085	277.0	2	23-JUN-83		POA	POA6-101
124		9.0	0.244	1129	1161	275.0	2	17-DEC-83		POA	POA6-103
125		10.0	0.291	1034	1061	281.0	2	14-DEC-79		POA	POA6-87
126		10.0	0.273	1053	1091	287.0	2	29-MAR-79		POA	POA6-88
127		10.0	0.276	1039	1084	287.0	2	17-DEC-84		POA	POA6-92
128		10.0	0.236	1044	1036	275.0	2			POA	POA6-93
129		10.0	0.271	1032	1136	280.0	2	05-AUG-82		POA	POA6-98
130		10.0	0.260	1070	1100	278.0	2	04-NOV-82		POA	POA6-99
131		10.0	0.258	1028	1162	265.0	2	24-MAR-83		POA	POA6-100
132		11.0	0.280	998		279.0	2	06-AUG-75		POA	POA6-77
133		11.0	0.274	1027	1063	281.0	2	24-JUL-80		POA	POA6-91
134		11.0	0.269	1022	1085	275.0	2	1-22-82		POA	POA6-96
135		12.0	0.274	1008	1041	278.0	2	07-FEB-80		POA	POA6-90
136		12.0	0.256	1049	1110	269.0	2	09-APR-81		POA	POA6-94
137		13.0	0.270	1019		275.0	2	11-MAY-70		POA	POA6-45
138		13.0	0.275	1021		281.0	2	11-DEC-74		POA	POA6-67
139		13.0	0.267	1033		276.0	2	17-FEB-77		POA	POA6-82
140		13.0	0.275	993	1106	273.0	2	31-JUL-79		POA	POA6-89
141		17.0	0.265	1085		288.0	2	13-APR-75		POA	POA6-80

Figure D-1. Igniter Ballistic Data, Sheet 3 of 3

COLD GAS EXPULSION TEST DATA

SN	AGE	BURST DISC	BURST PSIG	BLADDER VENDOR
160044	0000	0	098	-
-	0000	0	117	-
60095	0000	0	095	-
-	0000	0	119	-
200039	0000	0	074	-
-	0000	0	141	-
-	0000	0	113	-
-	0000	0	124	-
-	0000	0	113	-
-	0000	0	115	-
-	0000	0	112	-
170000	0000	0	100	-
-	0000	0	117	-
-	0000	0	112	-
-	0000	0	133	-
-	0000	0	099	-
-	0000	0	096	-
-	0000	0	099	-
-	0000	0	133	-
1122235	0001	0	102	-
430078	0001	0	117	-
490091	0001	0	100	-
1142215	0001	0	105	-
410079	0001	0	122	-
270019	0001	0	101	-
1062345	0001	0	130	-
1162338	0001	0	090	-
420068	0001	0	120	-
520088	0001	0	120	-
1112351	0001	0	115	-
470021	0001	0	082	-
1212354	0001	0	090	-
1182274	0001	0	106	-
440076	0001	0	112	-
460085	0002	0	115	-
500012	0002	0	100	-
600004	0002	0	110	-
530032	0002	0	095	-
1102217	0002	0	117	-
120002	0002	0	092	-
1052324	0002	0	114	-
50053	0002	0	097	-
10052	0002	0	100	-
130031	0002	0	099	-
1042315	0004	0	130	-
100014	0004	0	083	-
90098	0004	0	098	-
110101	0004	0	107	-
1082246	0004	0	095	-
150051	0004	0	098	-
210043	0004	0	110	-
180065	0004	0	108	-
80109	0004	0	120	-
640083	0004	0	142	-
730113	0006	0	123	-
550047	0006	0	100	-
1012323	0006	0	113	-
320007	0006	0	105	-

Figure D-2. Burst Disc Data, Sheet 1 of 4

230096	0006	0	126	-
910029	0006	0	098	-
570026	0006	0	104	-
200025	0006	0	100	-
560104	0006	0	095	-
1092232	0006	0	110	-
310020	0009	0	100	-
1072348	0009	0	092	-
1022269	0009	0	120	-
660013	0009	0	094	-
690085	0009	0	120	-
760099	0009	0	126	-
990033	0009	0	098	-
680086	0009	0	105	-
800024	0009	0	115	-
720062	0009	0	104	-
770115	0012	0	107	-
880016	0012	0	106	-
340015	0012	0	116	-
580037	0012	0	116	-
820050	0012	0	096	-
740087	0012	0	118	-
870090	0012	0	115	-
900100	0012	0	108	-
290028	0012	0	117	-
590049	0012	0	118	-
1032346	0018	0	110	-
1192308	0018	0	113	-
1222279	0018	0	097	-
1232304	0018	0	108	-
1202262	0018	0	110	-
1132340	0024	0	115	-
840106	0024	0	104	-
920046	0024	0	109	-
1362269	0024	0	111	-
1342347	0024	0	100	-
930023	0024	0	118	-
T159	0028	1	090	ARROWHEAD
T159	0028	3	090	ARROWHEAD
T159	0028	2	092	ARROWHEAD
T210	0028	3	112	ARROWHEAD
T159	0028	4	094	ARROWHEAD
T210	0028	1	120	ARROWHEAD
T210	0028	2	115	ARROWHEAD
T210	0028	4	100	ARROWHEAD
790059	0030	0	120	-
1332247	0030	0	100	-
128	0030	0	102	-
1302297	0030	0	105	-
1252257	0030	0	108	-
1432212	0036	0	111	-
1242368	0036	0	114	-
890067	0036	0	106	-
850077	0036	0	140	-
1262275	0042	0	132	-
1452294	0042	0	122	-
1272360	0042	0	110	-
1442298	0042	0	082	-
129226	0042	0	098	-
780064	0048	0	112	-
830006	0048	0	118	-
650057	0048	0	122	-

Figure D-2. Burst Disc Data, Sheet 2 of 4

1372220	0048	0	112	-
1462306	0048	0	110	-
1382238	0054	0	109	-
1392253	0054	0	095	-
1472286	0054	0	135	-
1492228	0054	0	118	-
1482227	0054	0	117	-
1402241	0060	0	120	-
1592343	0060	0	106	-
860082	0065	0	138	-
810066	0065	0	130	-
1422273	0067	0	132	-
1612322	0067	0	125	-
1622314	0067	0	127	-
1412332	0067	0	108	-
1602214	0067	0	100	-
1642253	0072	0	110	-
40011	0072	0	113	-
510058	0072	0	148	-
30093	0072	0	122	-
1502213	0072	0	111	-
1522239	0078	0	145	-
1512252	0078	0	137	-
1662312	0078	0	120	-
1672370	0078	0	135	-
960035	0084	0	121	-
750089	0084	0	103	-
950010	0084	0	113	-
1532249	0084	0	110	-
1682254	0084	0	123	-
1702264	0090	0	140	-
1692316	0090	0	115	-
1322267	0090	0	120	-
1552242	0090	0	13[illegible]	-
1542244	0090	0	120	-
350112	0096	0	113	-
940003	0096	0	115	-
970048	0096	0	093	-
1652331	0105	0	105	-
20013	0114	1	100	-
20013	0114	2	110	-
20013	0114	4	094	-
20013	0114	3	094	-
ABB0069	0135	1	115	US RUBBER
ABB0069	0135	3	108	US RUBBER
ABB0069	0135	2	101	US RUBBER
ABB0069	0135	4	125	US RUBBER
ABB0623	0172	4	117	ARROWHEAD
ABB0623	0172	3	111	ARROWHEAD
ABB0623	0172	1	094	ARROWHEAD
ABB0623	0172	2	111	ARROWHEAD
ABB1008	0174	1	117	ARROWHEAD
ABB0589	0174	3	126	ARROWHEAD
ABB0589	0174	4	131	ARROWHEAD
ABB0589	0174	2	112	ARROWHEAD
ABB0589	0174	1	107	ARROWHEAD
ABB1008	0174	4	098	ARROWHEAD
ABB1008	0174	3	124	ARROWHEAD
ABB1008	0174	2	108	ARROWHEAD
ABB1056	0196	4	113	ARROWHEAD
ABB1042	0196	1	083	ARROWHEAD
ABB1042	0196	2	135	ARROWHEAD

Figure D-2. Burst Disc Data, Sheet 3 of 4

ABB1042	0196	3	135	ARROWHEAD
ABB1056	0196	1	142	ARROWHEAD
ABB1042	0196	4	113	ARROWHEAD
ABB1056	0196	3	120	ARROWHEAD
ABB1056	0196	2	135	ARROWHEAD
ABB0555	0205	4	075	ARROWHEAD
ABB0555	0205	3	145	ARROWHEAD
ABB0555	0205	2	125	ARROWHEAD
ABB0555	0205	1	115	ARROWHEAD
CAC0041	0210	2	075	ARROWHEAD
CAC0041	0210	3	075	ARROWHEAD
CAC0041	0210	1	115	ARROWHEAD
CAC0041	0210	4	145	ARROWHEAD
1510	0224	4	100	ARROWHEAD
ABB1510	0224	1	113	ARROWHEAD
ABB1510	0224	2	113	-
1510	0224	3	103	ARROWHEAD
ABB0077	0228	3	140	ARROWHEAD
ABB0077	0228	4	125	ARROWHEAD
ABB0077	0228	2	140	ARROWHEAD
ABB0077	0228	1	125	ARROWHEAD
ABB0535	0230	3	112	US RUBBER
ABB0535	0230	4	125	US RUBBER
ABB0535	0230	2	120	US RUBBER
ABB0535	0230	1	125	US RUBBER
CMN5	0236	0	127	-
CMN3	0236	0	107	-
CLM3	0236	0	125	-
CN1	0236	0	098	-
ABB0800	0238	2	082	ARROWHEEAD
ABB0800	0238	3	075	ARROWHEAD
ABB0800	0238	4	107	ARROWHEAD
ABB0800	0238	1	093	ARROWHEAD

Figure D-2. Burst Disc Data, Sheet 4 of 4

VITON/DACRON COMPOSITE UNIROYAL AGING

Ø	1 AGE,MO	2 STS,PSI	3 STR,%	4 TEAR W/O	5 TEAR,W	6 ENVIORNMENT
1	6	2241	35	23.9	122	DL12Ø
2	6	2669	4Ø	26.6	127	"
3	6	31Ø3	44	25.1	116	"
4	6	2333	4Ø	26.4	126	"
5	6	261Ø	44	28.6	12Ø	ML12Ø
6	6	288Ø	42	29.3	123	"
7	12	2579	62	14.7	163	DL8Ø
8	12	2777	5Ø	13.7	166	"
9	12	27Ø9	42	14.5	148	DV8Ø
1Ø	12	2786	42	2Ø.3	143	"
11	12	25Ø6	56	19.3	179	ML8Ø
12	12	28Ø3	5Ø	19.4	198	"
13	12	2737	51	17.9	166	MV8Ø
14	12	2732	53	18.6	174	"
15	24	2628	6Ø	24.5	187	ML12Ø
16	24	2627	6Ø	22.8	177	"
17	24	2627	6Ø			"
18	24	2814	56	23.7	183	ML8Ø
19	24	277Ø	56	23.4	165	"
2Ø	24	2792	56			"

NOTE:

D - Distilled Freon
M - Montedison Freon
L - Liquid
V - Vapor
80 - 80°F Storage
120 - 120°F Storage

Figure D-3. Viton/Dacron Composite Uniroyal Aging

Appendix E

Qualification of Arrowhead AP-2707-3 (DIAK 2) Rubber

Qualification of Arrowhead AP-2702-3 Rubber as a Second Source for LITVC Bladder-Collector Assemblies (additional tests added to MRP-075)

BACKGROUND

Arrowhead AP-2707-3 was qualified for use in the original Minuteman program. In 1981 when DIAK 2, a compound originally used in AP 2707-3 was no longer available, Arrowhead AP-2707-5 was qualified which replaced DIAK 2 with DIAK 3. In 1984 Uniroyal 3094 replaced AP-2707-5 via qualification plan MRP-049C. Uniroyal, which has always used DIAK 2 as a curative, has been proven to be less susceptible to cracking than AP-2707-3 (DIAK 2) which is less susceptible to cracking than AP-2707-5 (DIAK 3).

INTRODUCTION

Additional tests were added to qualification plan MRP-075 in order to make a direct comparison to existing test data collected on earlier versions of Arrowhead rubber and presently qualified Uniroyal rubber. Tensile and tear tests were conducted on requalified Arrowhead Viton rubber and Viton/Dacron fabric composite over a -40°F to 300°F temperature range. In addition, a three year aging study was implemented in which Viton rubber and composite is stored in liquid Freon at 77°F.

RESULTS

Arrowhead AP-2707-3 (DIAK 2 Curative) Viton rubber and Viton/Dacron fabric composite tensile and tear properties are shown in Figures 1-6 with comparison to available data for AP-2707-5 (DIAK 3 curative) and Uniroyal 3094 taken from MRP-049C test results.

From Figure 1 it is seen Arrowhead rubber with DIAK 2 curative has similar tensile strength to previous Arrowhead (DIAK 3 curative) which is still lower than Uniroyal. The elongation of the new Arrowhead rubber is higher than both

Results (Cont)

previous Arrowhead and Uniroyal (refer to Figure 2). Although a great deal of variability exists in the trouser leg tear data, the new Arrowhead rubber has consistently higher tear strength than the previous Arrowhead rubber and is in the range of the Uniroyal tear strength (refer to Figure 3).

The new Arrowhead composite tensile strength and elongation are shown in Figures 4 and 5. Failure strain was taken at the point where the Dacron backing failed. No tensile testing was completed on rubber composite in the MRP-049C study for comparison.

The new Arrowhead composite tear strength is in the range of the previous Arrowhead composite which is higher than Uniroyal (refer to Figure 6).

CONCLUSIONS

The new Arrowhead AP-2707-3 rubber has elongation and tear strength greater than or equal to presently qualified Uniroyal 3094 and greater than previously qualified Arrowhead AP-2707-5. The results indicate AP-2707-3 will be less susceptible to cracking than earlier Arrowhead AP-2707-5.

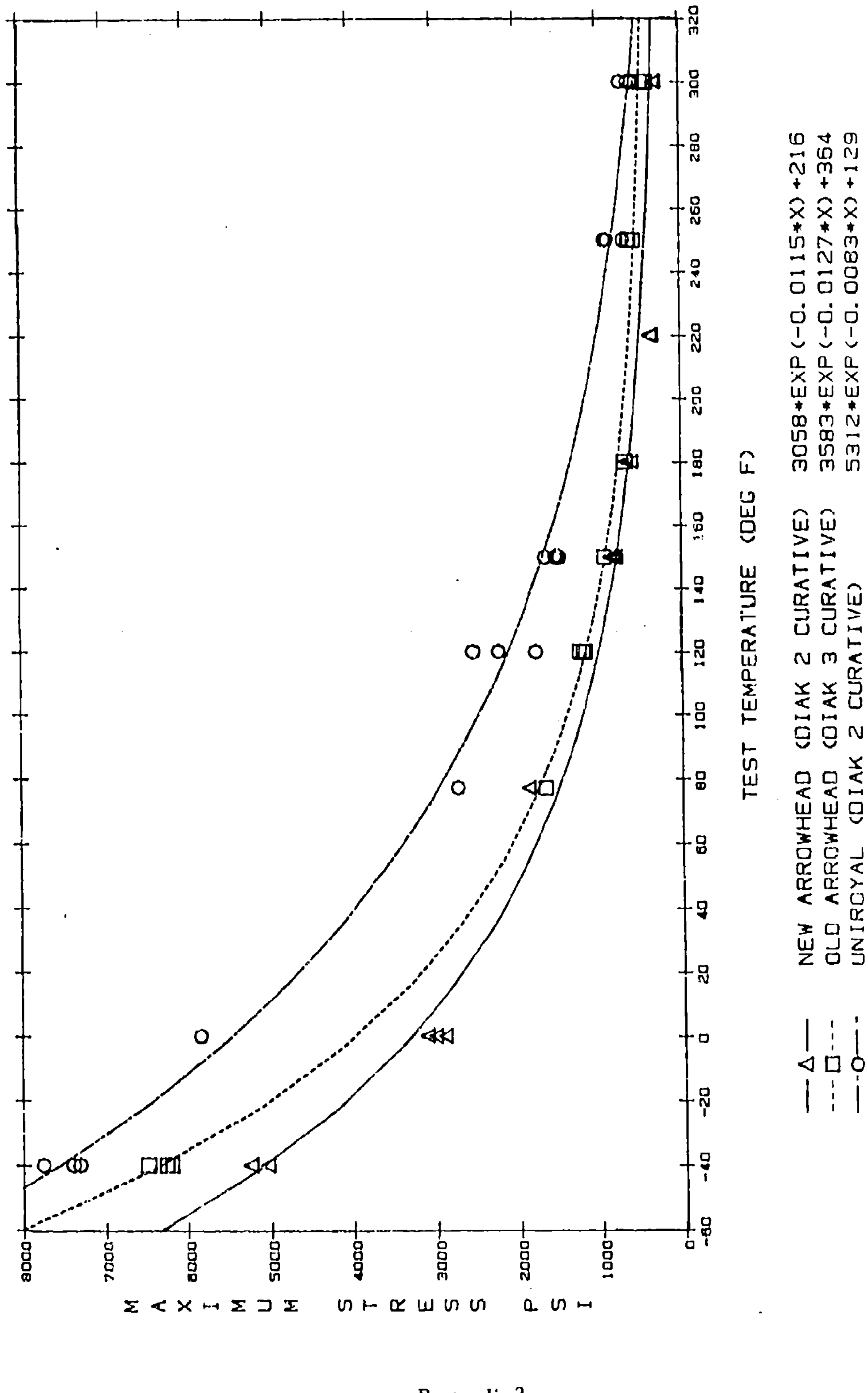


Figure E-1. Comparison of Requalified Arrowhead Viton Rubber Tensile Strength (ASTM D 1457) to Previous Arrowhead and Uniroyal Rubber

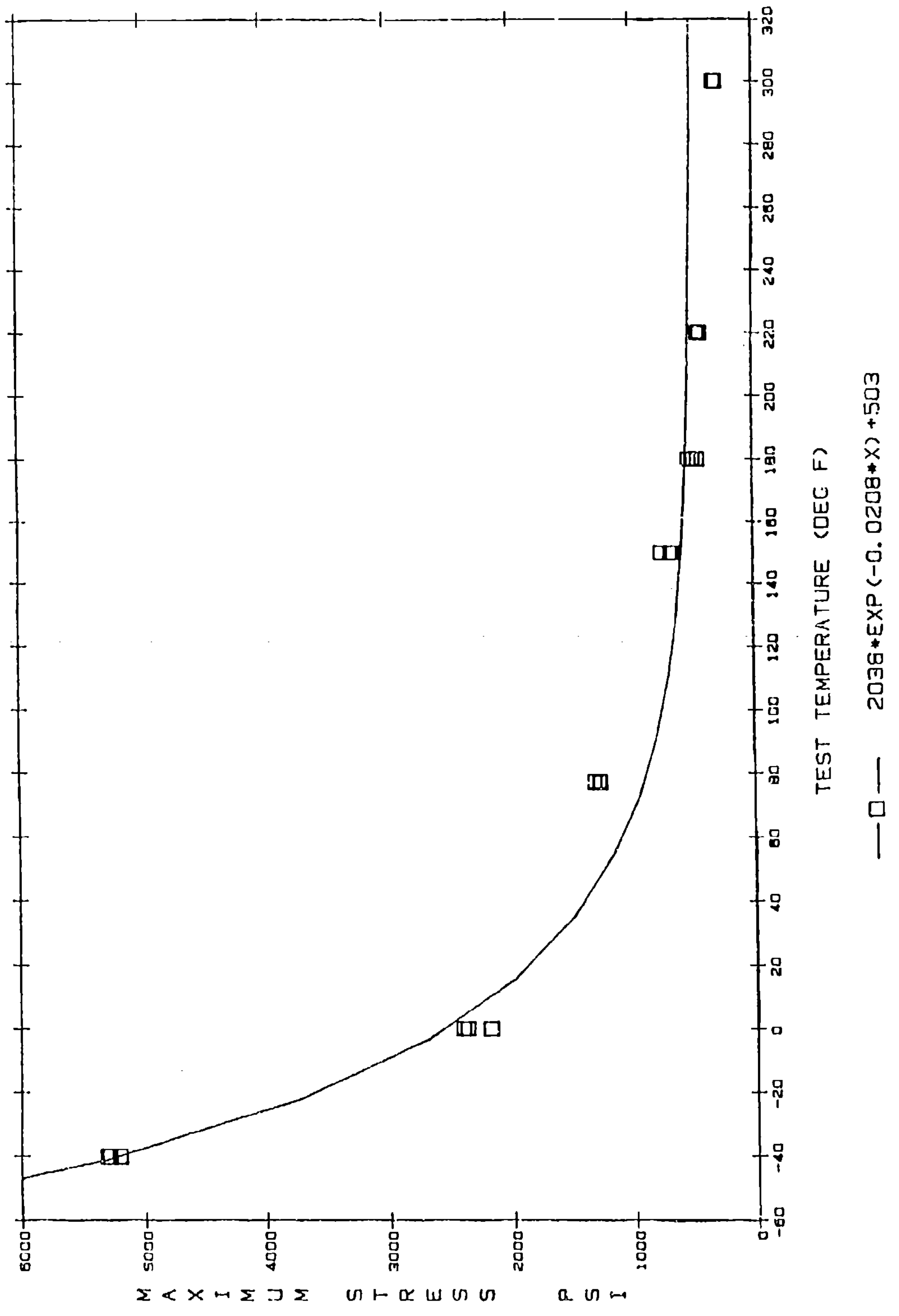


Figure E-4. Requalified Arrowhead Viton/Dacron Fabric Composite Tensile Strength (ASTM D 412)

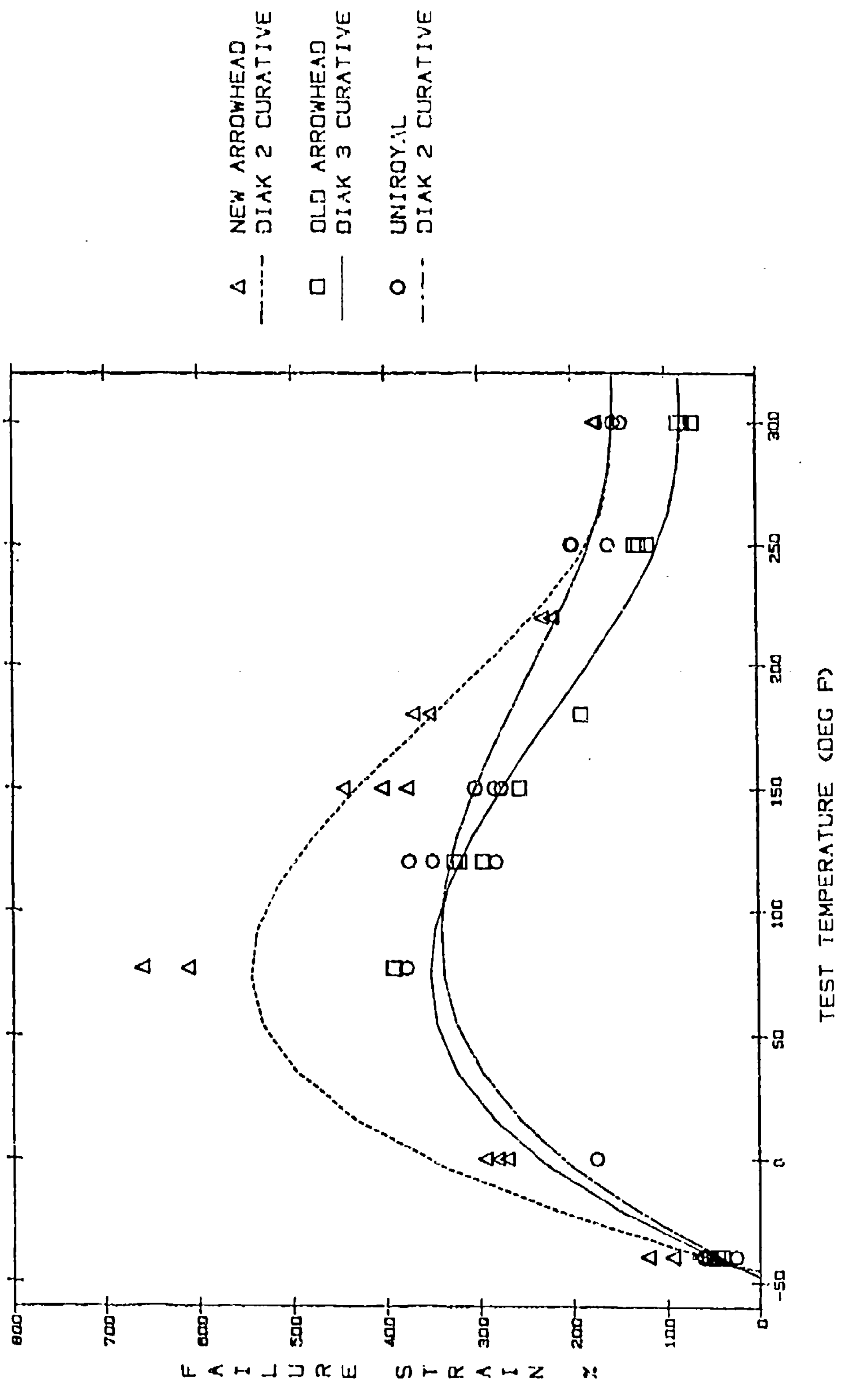


Figure E-2. Viton Rubber Failure Strain (ASTM D 1457) Comparison of Requalified Arrowhead Rubber to Previous Arrowhead and Uniroyal Rubber

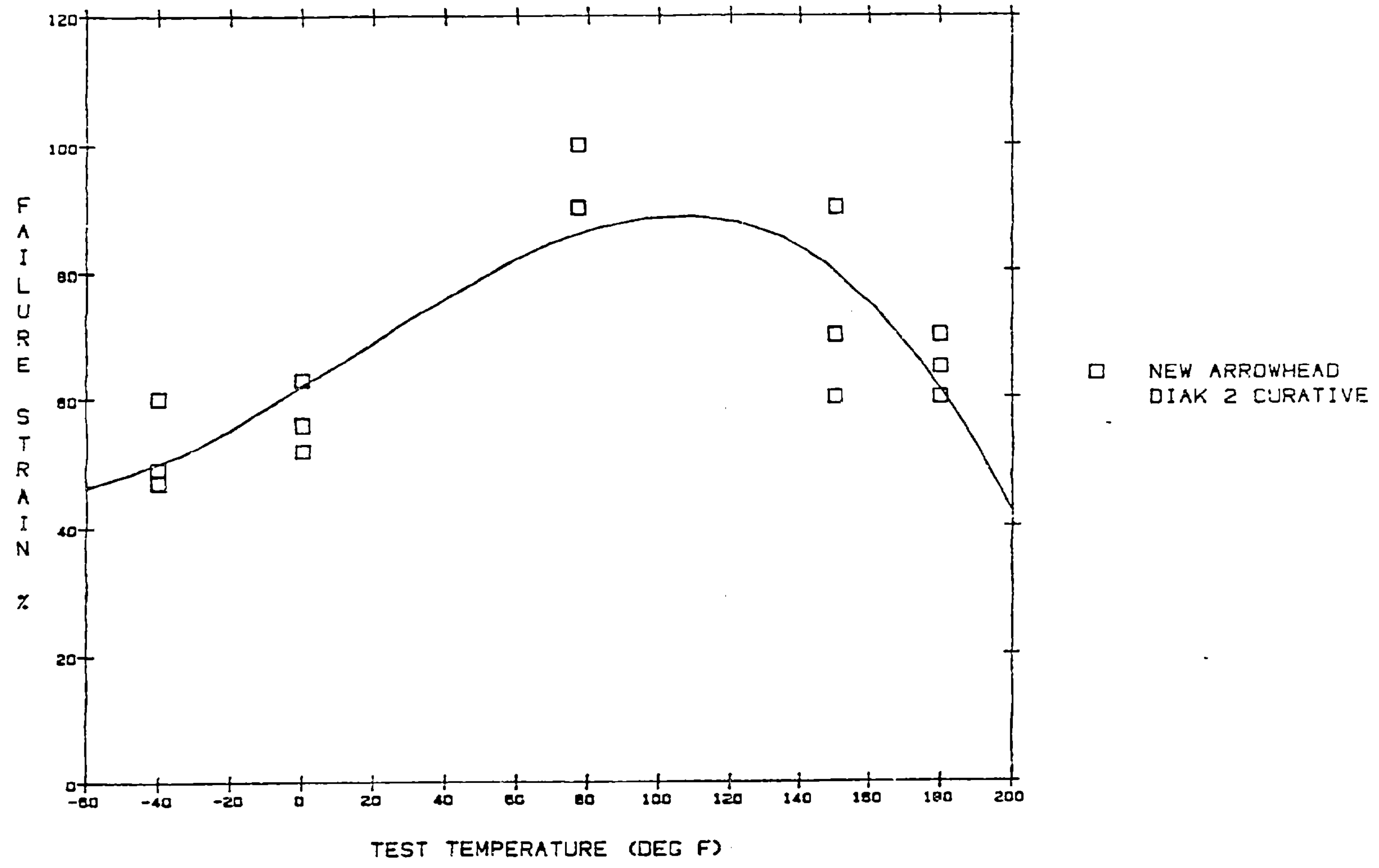


Figure E-5. Requalified Arrowhead Viton/Dacron Fabric Composite Failure Strain (ASTM D 412)

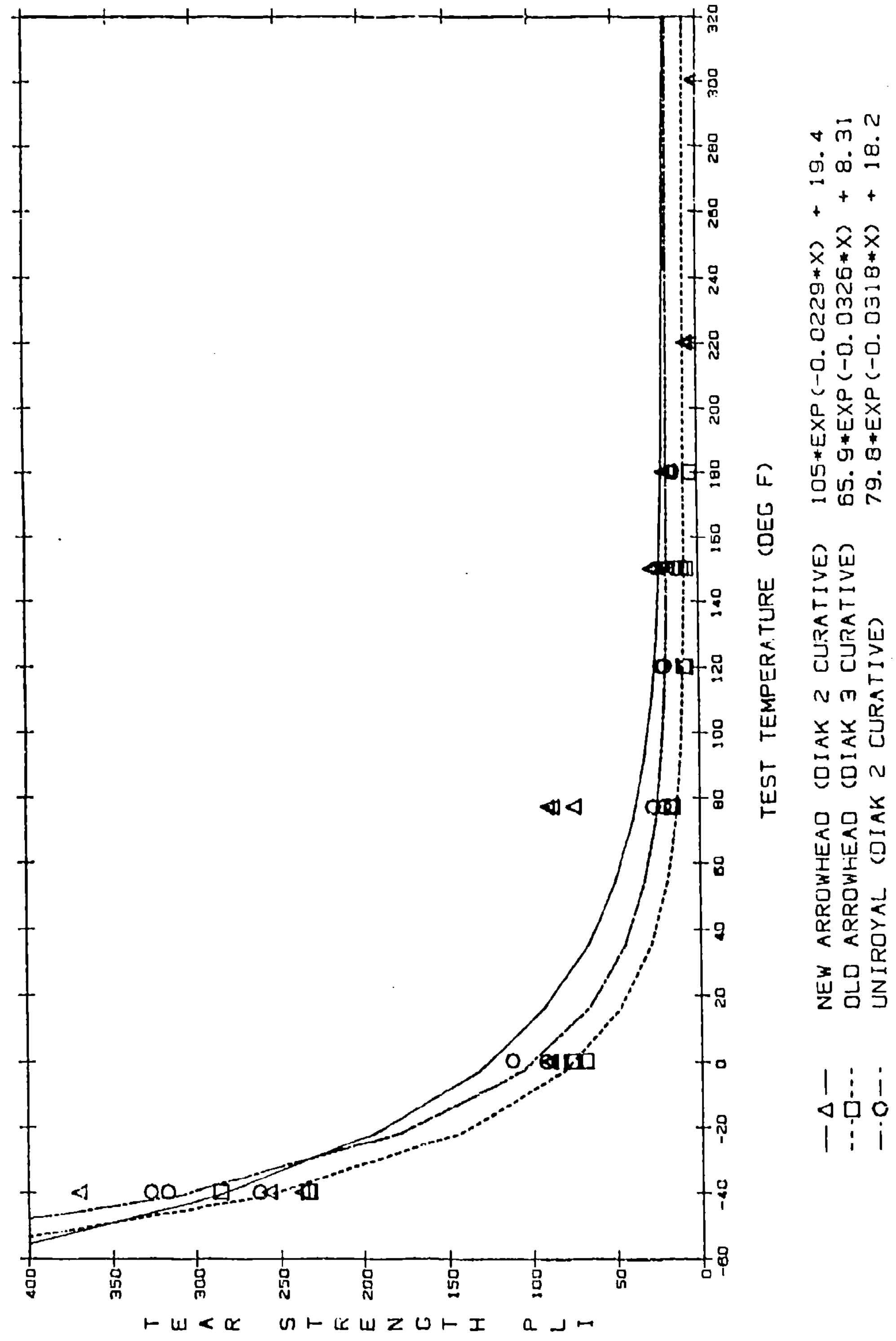


Figure E-3. Comparison of Requalified Arrowhead Viton Rubber Trouser Leg Tear Strength to Previous Arrowhead and Uniroyal Rubber

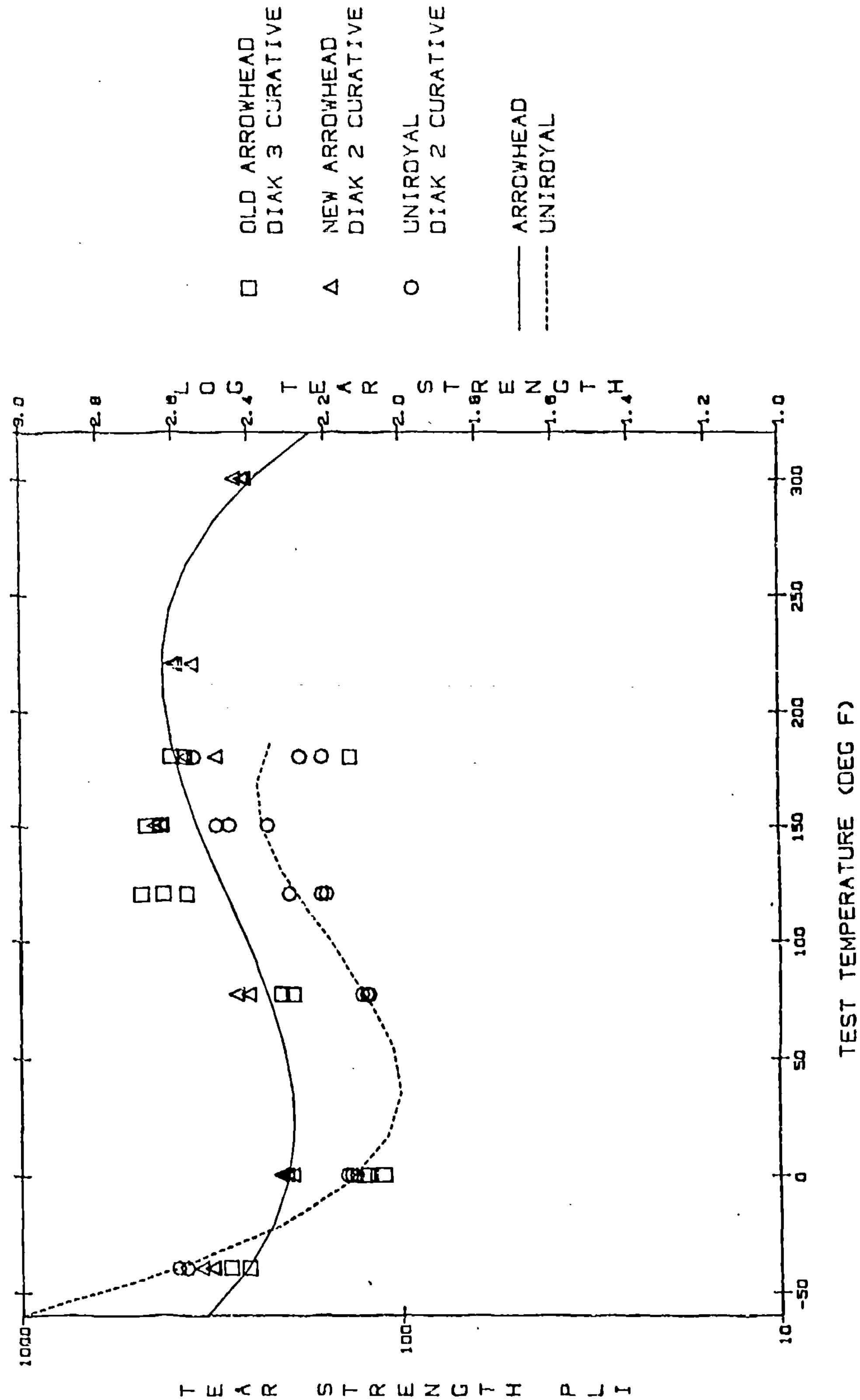


Figure E-6. Viton/Dacron Fabric Composite Trouser Leg Tear Comparison of Requalified Arrowhead Composite to Previous Arrowhead and Uniroyal Composite

SUPPLEMENTARY

INFORMATION

AD-A168269

Aerojet Strategic Propulsion Company

10 June 1986
2566:L5047
JEM:RLT:cs

Subject: Addition of Figure A-10 (Page A-32a) to Semi-Annual Report, Minuteman II/III, Stage II, Aging and Surveillance, Contract F42600-86-D-0093, CLIN 0002

To: Headquarters
Ogden ALC
United States Air Force
Hill Air Force Base, Utah 84056

Attention: MMGRMP/G. S. Porter

Reference: ASPC Letter L5030 Dated 28 May 1986 From J. E. McIntosh to MMGRMP/G. S. Porter, Subject: Contract Data Requirements List, Item A002, Contract F42600-86-D-0093, Report 0162-06-SAAS-36

1. The 28 May submittal per Reference (a) inadvertently omitted Figure A-10.

2. Please add the enclosed Page A32-a (Figure A-10) to your copy of the report.

3. Any questions regarding this addition should be directed to R. L. Thomas, ASPC, Dept. 2164, phone number (916) 355-4493.

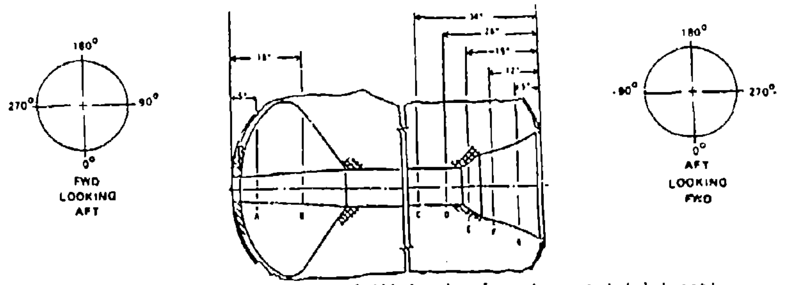
J. E. McIntosh
J. E. McIntosh, Manager
Contracts
Minuteman Programs

Enclosure: (1) Page A-32a (New Addition) of Report 0162-06-SAAS-36, Aging and Surveillance Program, Minuteman II/III Stage II Program Progress, Dated May 1986 (5 copies)

cc: OO-ALC/PMZEA/D. Leonhardt (w/o encl.)
OO-ALC/MMWRAM (w/o encl.)
OO-ALC/MMGRMP/J. Nelson (w/o encl.)
AFPRO/PD/F. Hall (w/o encl.)
AFPRO/EN/C. Lees (1 copy)
Cameron Station/DTIC
Alexander, VA 22314 (1 copy)

Motor S/N: AA 22304 (Hill) Cast Date: 6 November 1983 CTPB Vendor: Phillips

Test Date: 7 November 1985 Bay Temp (°F): Age at Test: 24 (Mos)



Average of All Angular Locations at Axial Location:

	A	B	C	D	E	F	G
Shore A2							
On-Surface (K_{77})	37.1	42				50.5	50.1
- E_o (psi)	969.2	1069.7				1376.7	1372.3
- σ_m (psi)	97.9	102.2				109.6	109.2
- ϵ_m (%)	18.2	16.8				14.8	14.7
- ϵ_b (%)	25.5	23.2				19.8	20.0
Temperature (°F)	73.6	73.6				74.1	74.1

Visual Observations

1. Forward Bondline
2. Aft Bondline
3. Forward Bore
4. Cylindrical Bore
5. Aft Nozzle Well
6. Other On-Surface motor data from Hill AFB. No visual observations were provided.

Figure A-10. Summary of On-Surface Testing Conducted on Stage II Motors, Page 11 of 11